KING COUNTY CONVEYANCE SYSTEM IMPROVEMENTS PROJECT

NORTH END PUMP STATION TESTING AND CALIBRATION

FINAL REPORT

FEBRUARY 2001

CERTIFICATE OF ENGINEER

The technical material contained in this report was prepared under the supervision and direction of the undersigned, whose seals, as professional engineers licensed to practice as such are affixed below.

Kevin J. Dour, P.E.

John M. Giaudrone, P.E.

ACKNOWLEDGEMENTS

The data in this report was collected through a collaboration with King County Staff, and Garry Struthers Associates, Inc. Field measuring equipment was installed and operated at each pump station by King County Staff. All pump station equipment was handled and operated by King County Staff. Garry Struthers Associates, Inc. provided direction, data recording, data analysis, and report preparation. HDR, Inc. provided project direction and technical input.

KING COUNTY

Bob Peterson – Conveyance System Improvements Project Manager

Ed Cox

Mike D'Ambrosia

Bruce Crawford

Andy Strehler

Cathy DeBlasio

Marv Clairmont

Ray Nass

Spence Louthan

GARRY STRUTHERS ASSOCIATES, INC.

John Giaudrone, P.E.

Kevin Dour, P.E.

HDR, INC.

Jim Peterson, P.E.

Sam Perry, P.E.

LIMITATIONS AND EXCEPTIONS

This report reflects data and findings at each pump station on the date of the site visit and pertains to the equipment tested on that date. No warranty is expressly stated or implied in this report with regard to the condition of the testing equipment and data collected. This report reflects our observations of field activities on the date of the site visit, and does not cover other conditions beyond the scope of the project that were not visible or evident during these field activities. Subsequent changes in conditions and/or adjustment to the pump station controls and/or equipment may result in station performance significantly different than what was experienced during our field activities. Therefore, the conclusions and recommendations herein are applicable only to the data collected on the date of the site visit.

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SECTION 1: INTRODUCTION, PURPOSE, AND SCOPE

1.1 PROBLEM STATEMENT

King County wishes to confirm flow data within pump stations in the NE Lake Washington Drainage Basin. There are data conflicts for flow measured between pump stations. That is, flow received at a downstream pump station is less than flow pumped from an upstream pump station. This is sometimes the case between the Hollywood and York Pump Station where measured flow between the stations does not match when it should. The County also wishes to check and verify measured flows at the pump station with CATAD (Computer Augmented Treatment and Disposal) system information received at the treatment plant.

1.2 PURPOSE OF THIS PROJECT

The purpose of this project is to test and field measure existing flow conditions for the pumps within the subject stations. The tasks will include measurement and documentation of readings from the permanent pump station flow meters during the tests. These readings will be compared to field measurements taken from a portable flow meter, tachometer, and pressure gauges. These data will be plotted on pump curves and compared to available manufacturer's pump curves and/or pump curves provided by King County modeling data. Force main flow and pressure data will also be collected and plotted. These plots will be compared to County system head curve information to determine the condition of the force mains.

Another purpose of the project is to compare data collected in the field with CATAD information transmitted from the pump stations and received at the treatment plant. From this comparison inconsistencies can be identified between field measurements, data readings from the control panel, and CATAD data received at the treatment plant. From these comparisons recommendations can be made to calibrate pump station meters and CATAD equipment to accurately read and transmit data. It is the County's desire to calibrate all equipment to within 10% of actual field measurements. This report will identify equipment readings that appear to be inconsistent and the degree to which adjustments need to be made in order to obtain accurate readings.

1.3 SCOPE OF WORK

This project originally included the following five pump stations in the North Lake Washington area:

- Kenmore Pump Station

- Woodinville Pump Station
- Hollywood Pump Station
- York Pump Station
- Matthews Park Pump Station

Four additional West Section pump stations were later added to the scope of work:

- Hidden Lake Pump Station
- Carkeek Park Pump Station
- North Beach Pump Station
- Interbay Pump Station (This site was visited but no testing was conducted).

SECTION 2: GENERAL MEASURING EQUIPMENT SETUP AND PROCEDURES

At each pump station, all equipment and panels were checked for calibration stickers. Particular equipment of interest included flow meters, pressure sensors, tachometers, and levels sensors. If a sticker was found, the date of the last calibration and the initials of the instrument technician were noted.

A portable strap-on flow meter was used to verify control panel and CATAD flow data. The meter was a Panametrics PT 868 Ultrasonic flow meter. The flow meter used ultrasonic transducers and Doppler shift to measure velocity within the pipe. The flow transducers can be set to measure velocity using a single-pass or double-pass method. In the single-pass method the two transducers are mounted on opposite sides of the pipe and a signal is transmitted between the two transducers across the pipe. The signal passes once across the pipe and velocity is read by measuring changes in the signal caused by the flow stream. In the double-pass method both transducers are mounted on the same side of the pipe. The signal from the first transducer passes across the pipe, reflects off the far wall, and returns to the other transducer.

Typically, the portable flow meter is located on the discharge or suction piping such that there is minimal turbulence from elbows, valves, and fittings. When an acceptable location could not be obtained on the force main discharge, the transducers would be mounted on the pump suction. According to the manufacturer's recommendations, the flow transducers should be located a minimum of ten pipe diameters from an upstream elbow/fitting and a minimum of five pipe diameters from a downstream elbow/fitting. The flow transducers were located with as much distance from upstream and downstream fittings as could be accommodated by the pipe arrangement.

A portable pressure gauge with calibration to National Bureau of Standards (NBS) was attached to the discharge end of each pump at an available fitting (except for Carkeek Park Pump Station where the gauges installed at the pump station were used). If possible, a pressure gauge was connected to the pump suction end to provide data for suction head. Few stations had fittings available to locate a pressure gauge on the pump suction. If a gauge could not be located on the pump suction, net positive suction head was determined from the wet well elevation and a calculation of head loss through the pump inlet fittings.

Reflective tape was placed on each pump's drive shaft and a hand-held tachometer was used to measure the pump speed. This was used to compare the speed readings at the control panel and for data correction calculations when plotting the pump curve.

SECTION 3: PUMP TESTING PROTOCOL

A measurement and testing strategy specific to each pump station was developed based upon the configuration of the pump station, the station controls, in-station flow metering equipment, speed control of the pumps, pressure measurement within the pump station, and the typical operating sequence of the pumps. The measurement and testing strategy at each station was designed to create a pump curve, with a minimum of 3 to 4 points, for each pump based upon field data. Data was taken on several pump runs at different points on the system head curve. Data was collected from field measurement instruments and from the station's control panel.

The following data was recorded from the pump station's control panel, if available:

- Wet well elevation
- Motor Operating Amps
- Total Flow of Pump Station
- Individual Pump Flow
- Pump Speed
- Time

The following information and data were recorded at the pump floor using the portable measuring equipment:

- Individual Pump Flow
- Combined Pump Flow (where possible)
- Discharge Pressure
- Suction Pressure (if available)
- Pump Speed
- Time

PUMP STATIONS BACKGROUND AND ANALYSIS

This section presents a brief background summary of each of the pump stations included in the scope of work. It discusses the station relationship within the North Lake Washington System, key issues discovered during testing, and specific measurement equipment setups. The recorded test data is also presented for each pump station along with the results of the data analysis. A summary of conclusions and recommendations for each pump station is presented in the following section.

SECTION 4 KENMORE PUMP STATION

4.1 Background

The Kenmore Pump Station is located at the north end of Lake Washington where the Sammamish River flows into Lake Washington. It receives flow from the Swamp Creek Interceptor to the north, the Inglewood Interceptor to the South and the discharge from the Woodinville Pump Station to the east. This station pumps to the Lake Line or alternately to the Logboom storage structure. Wastewater then continues southward along the west shore of Lake Washington to Matthews Park Pump Station.

4.2 Pump Station Design Information

Key design information for the Kenmore Pump Station is summarized in the table below.

Kenmore Pump Station Elevation Information (Metro Datum)

Pump Room Floor	92.50 ft
Wet Well Grating	102.00 ft
Motor Room Floor	106.50 ft
Overflow Elevation	116.50 ft
Control Room Floor	128.00 ft

Kenmore Pump Station Pump and Motor Information

Pumps #1 and #4:	
Pump:	
Model:	Wemco-Hidrostal, model H8DOL, vertical-dry pit
Capacity:	2,350 gpm at 32 feet TDH at 1,150 rpm
Impeller Size:	16.14 inch diameter
Motor:	
Model:	General Electric, model 5x6255XM1B; frame C365HP16
Rating:	50 hp at 1,170 rpm, 230/460 V, 130/65 A, 3-phase
Pumps #2 and #3:	
Pump:	
Model:	Wemco-Hidrostal, type L20-D, vertical-dry pit
Capacity:	8,000 gpm at 24 ft TDH with minimum efficiency of 76.5% at 600 rpm, minimum/maximum speeds: 450/650
Motor:	
Model:	Reliance XE
Rating:	125 hp at 710 rpm, 460 V, 60 Hz.
Variable Speed Drive	
Model:	Robicon Corp; 480 V, 3-phase, 60 Hz.

4.3 Key Points and Issues

There were several key points and issues discovered during the testing and data analysis of the Kenmore Pump Station. They are summarized below:

- The County does not have manufacturer pump curves for Pumps #1 and #4. Curves were provided from the County's modeling database.

- All pumps have a non-clog ("single port") impeller.

- The check valves barely open on the smaller pumps (Pumps #1 and #4). This is because the inlets and discharges are too large. This resulted in very low velocities on the discharge and inlet sides of the pumps. This causes solids buildup problems in the wet well near the #1 and #4 pump inlets and in the discharge piping.

- The flow and pressure readings on Pumps #1 and #4 were erratic due to the check valves "rocking". Pumps #2 and #3 gave steadier readings at higher flows and more erratic readings at lower flows (again, because the check valves were rocking).

- It was noted that the transducer crystals on the pump station's flow meter could deteriorate over time. The pump station flow meter is a Doppler type flow meter.

- Pumps #2 and #3 (20" Pumps) are difficult to re-prime due to the location of the vents. There is a high point in the volute casings above the location of the vents which prevents the air from purging out of the casings. To prime, the pumps are run at high speed to entrain the air in the discharge flow. This results in vibration. The vents need to be relocated to the highest point in the volutes to allow adequate venting. The location of the vents on the #1 and #4 pumps allow for complete bleeding and priming.

4.4 Measuring Equipment Setup at Kenmore Pump Station

This was the only pump station that was connected to a data logger to record real time data readings. It was left in place to take readings throughout the night and to check against the CATAD logged data at the treatment plant. On the pump floor, a pressure gauge with pressure transducer was installed on the pump discharge. A strap-on flow meter was positioned on the force main near the pump room ceiling. The meter installation required paint to be chipped from the force main and a thickness measurement of the pipe wall where the flow transducers were mounted was taken using an ultrasonic thickness gage. Figure DIA – 1 in the Appendix is a schematic diagram of the piping and approximate equipment locations.

Pressure gauge readings were read directly and hand recorded. Additionally, a 4-20 ma signal from the pressure transducer was sent directly to the datalogger and recorded on the portable notebook computer. The elevation from the centerline of the volute to the pump floor was measured to correct the pressure gauge reading. The discharge pressure was used to calculate total dynamic head.

The wet well level was recorded for each pump run from the control panel. The wet well level bubbler was checked by measuring the distance to the water surface from the grate. When the elevation was calculated using the grate elevation from the record drawings, it

checked with the control panel elevation within 0.03 feet. (Panel reading was higher than field measurement).

4.5 Measuring Protocol at Kenmore Pump Station

4.5.1 Testing Sequence

The pumps were tested over a two-day period. The first day of testing was November 2, 1999. The variable speed pumps (Pump #2 and #3) were tested on this day. A total of 14 test runs were taken on this day, 7 runs for pump #2 and 7 runs for pump #3. Each pump was operated alone at different speeds to obtain discrete operating points along the system head curve.

The second day of testing was November 3, 1999. The constant speed pumps (Pumps #1 and #4) were tested on this day. A total of 10 test runs were taken on this day, 3 runs for Pump #1, 3 runs for Pump #4, and 4 additional runs for Pump #3. In order to obtain discrete points on the system head curve for the constant speed pumps, these pumps were run alone and in tandem with the variable speed pumps. This changed the pressure conditions in the force main resulting in different head and discharge conditions for the constant speed pumps.

4.5.2 Measuring Protocol – Pump Floor

Data were read on the pump floor as follows:

- Flow: the pump flow was read directly from the Panametrics flow meter data display and hand recorded. It was also "captured" on the datalogger and recorded in the notebook computer.

- Pressure: the discharge pressure from the pump was read directly from the calibrated dial gauge (test pressure meter) and hand recorded. The 4-20ma signal from the pressure transducer, attached to the test pressure meter, was also "captured" and sent to the datalogger and recorded in the notebook computer.

- Pump Speed: the pump speed was read from the drive shaft using the hand-held tachometer. The pump speed was manually recorded. No pump speed information was recorded from the pump floor to the datalogger.

- Time: the time of the reading was taken from the notebook computer that was synchronized with the clock on the control panel.

4.5.3 Measuring Protocol – Main Control Room

Data were read in the main control room as follows:

- Flow: the pump flow was read directly from the main control panel. This data was also being sent to the datalogger and notebook computer from the main control panel.

- Pressure: no discharge pressure reading was available on the main control panel.

- Wet Well Elevation: the wet well elevation was read from the control panel at the time of the pump run. This data was also being sent to the datalogger and notebook computer from the main control panel.

- Pump Speed: the pump speed was read directly from the control panel at the time of the pump run. The pumps were run at different speeds to obtain the desired number of points on the system head curve. This data was also being sent to the datalogger and notebook computer from the main control panel.

- Motor Operating Amps: the operating amps of the pump motor were recorded for reference for each pump run from the in-station ammeter.

- Time: the time of the reading was read from the control panel. The pump shutdown time was also recorded to coordinate with the CATAD log.

4.6 Kenmore Pump Station: Collected Data

This section presents and compares the data collected at the Kenmore Pump Station. Data were collected on the pump floor using portable measuring devices, at the control panel, and from the CATAD system.

Table 1 presents the hand recorded data taken on November 2nd and 3rd. Table 2 summarizes the differences between the hand-recorded data on the pump floor and the corresponding data recorded in the control room. This gives an indication of the error present between the control panel readings and the data readings from the portable measuring devices.

Table 3 summarizes and compares the pump station data and CATAD data. The table compares pump-on time, wet well elevation, pump flow, and pump speed.

Figures A-1 through A-6 in the Appendix graph the data recorded at the pump floor against the data recorded from the control panel. If the data matched exactly, it would plot along a 1:1 slope on the graph. In the same manner, Figures A-7 through A-13 in the Appendix graph the data recorded at the pump floor against the CATAD data. These plots show how the data compare.

Table 1: Kenmore Pump Station Recorded Data

Run #	Date	Time (Main Floor)	Pump #	Wet Well Elev. (ft)	Amps	Control Panel Flow (MGD)	*Control Panel Flow (gpm) (Calculated)*	Speed (rpm)	Time (Pump Floor)	Test Meter Flow (gpm)	Observed Flow Variance (gpm)	Pressure Gage (psi)	*Pressure (ft) (Calculated)*	Transducer (millivolts)	Hand-Held Tachometer (rpm)
01	11/2/99	10:09	3	98.4	155	17.00	*11,806*	657	10:21	15,700		8.75	*20.2*	67.0	673.3
02	11/2/99	10:21	3	98.45	150	15.50	*10,764*	619	10:31/:34	13,600		8.6	*19.8*	66.3	635.7
03	11/2/99	10:33	3	98.6	133	13.90	*9,653*	579	10:43/:46	11,800	200	8.3	*19.2*	66.4	594.7
04	11/2/99	10:42	3	98.77	122	12.10	*8,403*	540	10:53/:54	10,400	200	8.2	*18.9*	63.7	554.8
05	11/2/99	10:54	3	98.99	113	10.50	*7,292*	499	11:05/:06	8,720	100	8.2	*18.9*	63.6	513.5
06	11/2/99	11:06	3	99.11	105	8.50	*5,903*	461	11:17/:18	7,200	100	8.0	*18.5*	62.8	474.2
07	11/2/99	11:19	3	99.36	97	6.30	*4,375*	421	11:29/:30	5,300	300	8.0	*18.5*	62.3	432.8
07(a)	11/2/99	11:23	3	99.36	97	5.50	*3,819*	421							
08	11/2/99	14:01	2	97.18	143	19.90	*13,819*	632	14:11/:13	13,000	100	7.6	*17.5*	60.4	644.5
09	11/2/99	14:12	2	97.21	135	18.50	*12,847*	598	14:22	11,800		7.6	*17.5*	59.6	607.4
10	11/2/99	14:21	2	97.32	125	15.60	*10,833*	550	14:32/:33	10,200	300	7.5	*17.3*	59.0	559.0
11	11/2/99	14:31	2	97.51	114	13.70	*9,514*	501	14:41/:42	8,300	200	7.4	*17.1*	57.7	510.3
12	11/2/99	14:42	2	97.69	105	9.70	*6,736*	450	14:53	6,156	200	7.4	*17.1*	58.2	458.4
13	11/2/99	14:54	2	97.93	97	5.60	*3,889*	401	15:05	3,750	150	7.4	*17.1*	57.7	408.0
14	11/2/99	15:04	2	97.09	142	19.30	*13,403*	632	15:15	12,700	200	8.25	*19.0*	63.9	641.8
14a	11/2/99	15:05	3	97.03	159	16.10	*11,181*	657					*0*		
21	11/3/99	9:37	1	97.75	51	5.50	*3,819*		9:48/:51	3,850	150	9.3	*21.5*	72.5	1188.0
21a	11/3/99	9:37	3	97.75	158	16.40	*11,389*	657					*0*		
22	11/3/99	9:52	1	97.06	51.5	5.30	*3,681*		10:02/:03	3,700	100	9.6	*22.2*	74.9	1186.0
22a	11/3/99	9:52	3	97.06	157	16.20	*11,250*	657					*0*		
22b	11/3/99	9:52	2	97.06	114	11.80	*8,194*	500					*0*		
23	11/3/99	10:06	1	97.78	51	4.90	*3,403*		10:18/:19	3,850	100	8.8	*20.3*	67.8	1186.0
23R	11/3/99	10:46	1	97.67	50.7	4.90	*3,403*		10:57/:59	3,950	150	8.6	*19.9*	68.3	1186.0
24	11/3/99	13:03	4	96.76	38.3	5.90	*4,098*		13:13	3,400	200	8.4	*19.4*	64.4	1187.0
25	11/3/99	13:21	4	96.93	42.8	5.80	*4,028*		13:31	3,370	100	9.0	*20.8*	70.6	1187.0
25a	11/3/99	13:21	3	96.93	157	16.00	*11,111*	656					*0*		
26	11/3/99	13:34	4	96.6	44.7	6.20	*4,306*		13:45	3,180	100	9.3	*21.5*	72.6	1186.0
26a	11/3/99	13:34	3	96.6	158	16.70	*11,597*	657					*0*		
26b	11/3/99	13:34	2	96.6	114.5	11.20	*7,778*	498					*0*		
27	11/3/99	14:52	3	96.66	158	16.90	*11,736*	656	15:02/:04	14,200	200	8.1	*18.7*	63.5	672.3
28	11/3/99	15:05	3	97.08	132	13.50	*9,375*	580	15:16/:17	11,800	100	7.95	*18.3*	60.6	595.6
29	11/3/99	15:15	3	97.53	114	11.30	*7,847*	502	15:26/:28	8,900	200	7.6	*17.5*	59.1	515.5
30	11/3/99	15:26	3	98.06	96	5.40	*3,750*	421	15:36/:37	5,230	50	7.5	*17.3*	58.6	432.4

Note: Columns in Italics are calculated and were not recorded in the field

Table 2: Kenmore Pump Station Summary of Errors Between Pump Floor and Control Room Data Readings

Run #	Date	Pump #	Control Panel Flow (MGD)	*Control Panel Flow (gpm) (Calculated)*	Test Meter Flow (gpm)	Flow Variance	Flow Difference (gpm)	% Difference Meter to Control Panel	% Difference Variance to Control Panel	Control Panel Speed (rpm)	Hand-Held Tachometer (rpm)	Speed Difference (rpm)	% Difference Tachometer to Control Panel
01	11/2/99	3	17.00	*11,806*	15,700		-3,894	-33.0%		657	673.3	-16.3	-2.5%
02	11/2/99	3	15.50	*10,764*	13,600		-2,836	-26.3%		619	635.7	-16.7	-2.7%
03	11/2/99	3	13.90	*9,653*	11,800	200	-2,147	-22.2%	2.1%	579	594.7	-15.7	-2.7%
04	11/2/99	3	12.10	*8,403*	10,400	200	-1,997	-23.8%	2.4%	540	554.8	-14.8	-2.7%
05	11/2/99	3	10.50	*7,292*	8,720	100	-1,428	-19.6%	1.4%	499	513.5	-14.5	-2.9%
06	11/2/99	3	8.50	*5,903*	7,200	100	-1,297	-22.0%	1.7%	461	474.2	-13.2	-2.9%
07	11/2/99	3	6.30	*4,375*	5,300	300	-925	-21.1%	6.9%	421	432.8	-11.8	-2.8%
07(a)	11/2/99	3	5.50	*3,819*						421			
08	11/2/99	2	19.90	*13,819*	13,000	100	819	5.9%	0.7%	632	644.5	-12.5	-2.0%
09	11/2/99	2	18.50	*12,847*	11,800					598	607.4	-9.4	-1.6%
10	11/2/99	2	15.60	*10,833*	10,200	300	633	5.8%	2.8%	550	559.0	-9.0	-1.6%
11	11/2/99	2	13.70	*9,514*	8,300	200	1,214	12.8%	2.1%	501	510.3	-9.3	-1.9%
12	11/2/99	2	9.70	*6,736*	6,156	200	580	8.6%	3.0%	450	458.4	-8.4	-1.9%
13	11/2/99	2	5.60	*3,889*	3,750	150	139	3.6%	3.9%	401	408.0	-7.0	-1.7%
14	11/2/99	2	19.30	*13,403*	12,700	200	703	5.2%	1.5%	632	641.8	-9.8	-1.6%
14a	11/2/99	3	16.10	*11,181*						657			
21	11/3/99	1	5.50	*3,819*	3,850	150	-31	-0.8%	3.9%		1188.0		
21a	11/3/99	3	16.40	*11,389*						657			
22	11/3/99	1	5.30	*3,681*	3,700	100	-19	-0.5%	2.7%		1186.0		
22a	11/3/99	3	16.20	*11,250*						657			
22b	11/3/99	2	11.80	*8,194*						500			
23	11/3/99	1	4.90	*3,403*	3,850	100	-447	-13.1%	2.9%		1186.0		
23R	11/3/99	1	4.90	*3,403*	3,950	150	-547	-16.1%	4.4%		1186.0		
24	11/3/99	4	5.90	*4,097*	3,400	200	697	17.0%	4.9%		1187.0		
25	11/3/99	4	5.80	*4,028*	3,370	100	658	16.3%	2.5%		1187.0		
25a	11/3/99	3	16.00	*11,111*						656			
26	11/3/99	4	6.20	*4,306*	3,180	100	1,126	26.1%	2.3%		1186.0		
26a	11/3/99	3	16.70	*11,597*						657			
26b	11/3/99	2	11.20	*7,778*						498			
27	11/3/99	3	16.90	*11,736*	14,200	200	-2,464	-21.0%	1.7%	656	672.3	-16.3	-2.5%
28	11/3/99	3	13.50	*9,375*	11,800	100	-2,425	-25.9%	1.1%	580	595.6	-15.6	-2.7%
29	11/3/99	3	11.30	*7,847*	8,900	200	-1,053	-13.4%	2.5%	502	515.5	-13.5	-2.7%
30	11/3/99	3	5.40	*3,750*	5,230	50	-1,480	-39.5%	1.3%	421	432.4	-11.4	-2.7%

Note: Columns in Italics are calculated and were not recorded in the field

Table 3: Kenmore Pump Station Summary of Errors Between Pump Station Data and CATAD Data

Run #	Date	Time Control Panel	Time Pump Floor	Pump On CATAD	Pump #	Control Panel WW El.	CATAD WW El.	% Difference Control Panel to CATAD	Control Panel Flow (mgd)	Portable Flow Meter (mgd)	CATAD Flow (mgd)	% Difference Control Panel to CATAD	% Difference Portable Meter to CATAD	Control Panel (rpm)	Hand-Held Tachometer (rpm)	CATAD (rpm)	% Difference Control Panel to CATAD	% Difference Tachometer to CATAD
01	11/2/99	10:09	10:21	10:28	3	98.4	98.31	-0.09%	17.00	22.61	5.73	-196.68%	-294.55%	657	673.3	434.84	-51.09%	-54.84%
02	11/2/99	10:21	10:31/:34	10:39	3	98.45	98.43	-0.02%	15.50	19.58	5.98	-159.20%	-227.49%	619	635.7	434.67	-42.41%	-46.25%
03	11/2/99	10:33	10:43/:46	10:51	3	98.6	98.53	-0.07%	13.90	16.99	5.88	-136.39%	-188.98%	579	594.7	434.67	-33.20%	-36.82%
04	11/2/99	10:42	10:53/:54	11:01	3	98.77	98.62	-0.15%	12.10	14.98	5.66	-113.78%	-164.59%	540	554.8	434.67	-24.23%	-27.64%
05	11/2/99	10:54	11:05/:06	11:13	3	98.99	99.00	0.01%	10.50	12.56	0.00	n/a	n/a	499	513.5	207.54	-140.44%	-147.42%
06	11/2/99	11:06	11:17/:18	11:19	3	99.11	98.53	-0.59%	8.50	10.37	16.62	48.86%	37.62%	461	474.2	660.93	30.25%	28.25%
07	11/2/99	11:19	11:29/:30	11:32	3	99.36	98.64	-0.73%	6.30	7.63	14.86	57.60%	48.64%	421	432.8	623.83	32.51%	30.62%
08	11/2/99	14:01	14:11/:13	12:32	2	97.18	97.19	0.01%	19.90	18.72	7.08	-181.07%	-164.41%	421	644.5	429.29	1.93%	-50.13%
09	11/2/99	14:12	14:22	14:25	2	97.21	97.46	0.26%	18.50	16.99	14.32	-29.19%	-18.66%	632	607.4	538	-17.47%	-12.90%
10	11/2/99	14:21	14:32/:33	14:35	2	97.32	97.46	0.14%	15.60	14.69	14.86	-4.98%	1.16%	598	559	538	-11.15%	-3.90%
11	11/2/99	14:31	14:41/:42	14:46	2	97.51	97.46	-0.05%	13.70	11.95	14.86	7.81%	19.57%	550	510.3	538	-2.23%	5.15%
12	11/2/99	14:42	14:53	14:57	2	97.69	97.37	-0.33%	9.70	8.86	14.86	34.72%	40.35%	501	458.4	538	6.88%	14.80%
13	11/2/99	14:54	15:05	15:09	2	97.93	97.16	-0.79%	5.60	5.40	20.07	72.10%	73.09%	450	408	635.27	29.16%	35.78%
14	11/2/99	15:04	15:15	15:19	2	97.09	97.22	0.13%	19.30	18.29	18.44	-4.66%	0.82%	401	641.8	635.27	36.88%	-1.03%
21	11/3/99	9:37	9:37	10:27	1	97.75	98.06	0.32%	5.50	5.54	5.90	6.78%	6.03%	na	1188	na	na	na
22	11/3/99	9:52	10:02/:03/:	11:59	1	97.06	97.05	-0.01%	5.30	5.33	5.44	2.57%	2.06%	na	1186	na	na	na
23	11/3/99	10:06	10:18/:19	11:13	1	97.78	97.69	-0.09%	4.90	5.54	4.18	-17.22%	-32.63%	na	1186	na	na	na
23R	11/3/99	10:46	10:57/:59	12:13	1	97.67	97.50	-0.17%	4.90	5.69	4.29	-14.22%	-32.59%	na	1186	na	na	na
24	11/3/99	13:03	13:13	13:13	4	96.76	96.65	-0.11%	5.90	4.90	5.60	-5.36%	12.57%	na	1187	na	na	na
25	11/3/99	13:21	13:31	13:30	4	96.93	96.90	-0.03%	5.80	4.85	6.24	7.05%	22.23%	na	1187	na	na	na
26	11/3/99	13:34	13:45	13:43	4	96.6	96.62	0.02%	6.20	4.58	6.11	-1.47%	25.05%	na	0	na	na	na
27	11/3/99	14:52	15:02/:04	14:57	3	96.66	96.49	-0.18%	16.90	20.45	16.95	0.29%	-20.64%	656	672.3	660.76	0.72%	-1.75%
28	11/3/99	15:05	15:16/:17	15:11	3	97.08	97.03	-0.05%	13.50	16.99	13.40	-0.75%	-26.81%	580	595.6	585.34	0.91%	-1.75%
29	11/3/99	15:15	15:26/:28	15:23	3	97.5	97.03	-0.48%	11.30	12.82	11.23	-0.62%	-14.12%	502	515.5	506.1	0.81%	-1.86%
30	11/3/99	15:26	15:36/:37	15:34	3	97.62	98.00	0.39%	5.40	7.53	5.26	-2.66%	-43.18%	421	432.4	426.17	1.21%	-1.46%

4.7 Kenmore Pump Station – Data Analysis

The data collected during the pump runs was analyzed and corrected in order to develop pump curves. These pump curves were compared to manufacturer's pump curves and/or pump data provided by the County.

The pump data were corrected by using the pump affinity laws. These laws correct flow and pressure data collected at a given pump speed to a set curve speed. This is done by multiplying the square of the ratio of curve speed to pump speed to correct for head, and multiplying the ratio of curve speed to pump speed to correct for flow.

The total differential head is calculated by adding the discharge head, velocity head, and suction head; and subtracting from this total the inlet head. The suction head for the pump station is calculated by adding the minor losses and friction losses of the inlet piping. These are calculated for each pump run based upon the measured flow.

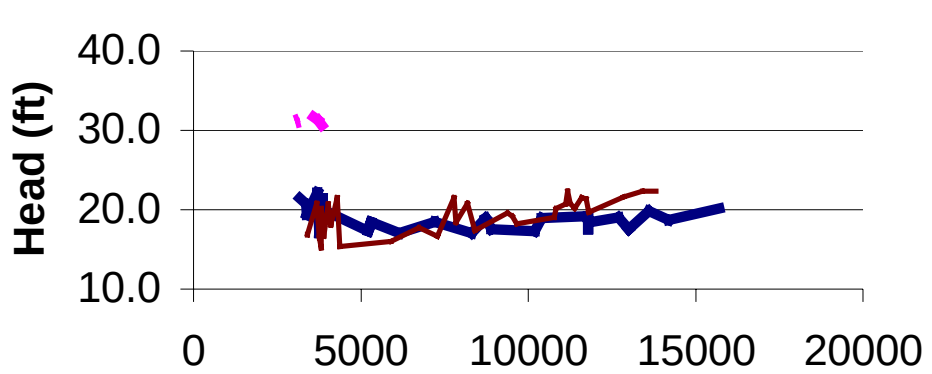
Table 4 summarizes the data correction calculations and shows the corrected pump data. Pump #2 and #3 have been corrected to a pump speed of 620 rpm, Pump #1 and #4 have been corrected to a pump speed of 1,150 rpm. These speeds are within the optimal operating range for the variable speed and constant speed pumps.

Figures 1 through 5 are plots of the corrected pump curves. Also shown on each figure is the factory curve generated from data provided by the pump manufacturer and/or the County's modeling database. Additionally, the force main's system head curve is plotted from the data collected in the field and from County data. This is done to show the condition of the force main compared to County data. The intersection of the pump curve and system head curve indicates an operating point where the pump should operate at the plotted pump speed. In some cases there is no intersection because the pump tests were not conducted at high enough speeds to give pump points far enough along the system head curve.

Table 4: Kenmore Pump Station – Table of Corrected Pump Data

							P #1	P #2	P #3	P #4						
		ELEVATION OF PUMP CENTER LINE					95.4	95.5	95.5	95.3						
		DISCH. GAGE HEIGHT					95.4	95.5	95.5	95.3						
		FIELD DATA						**CORRECTED DATA**					CORRECTED			FLOW FROM
RUN NO.	PUMP NO.	BUBBLER LEVEL (ft)	TEST METER FLOW (gpm)	DISC. PRESS. (psi)	SPEED RPM		INLET HEAD	SUCTION HEAD	DISCH. HEAD (ft)	VELOCITY HEAD LOSS	TEST TOTAL HEAD		CURVE RPM	HEAD	FLOW	FACTORY CURVE
FIRST RUN, PUMP #3 BETWEEN 10:09 AND 11:23																
1	3	98.4	15,700	8.75	673		2.9	2.4	20.2	4.4	24.1		620	**20.4**	**14457**	12000
2	3	98.5	13,600	8.6	636		3.0	1.8	19.9	3.3	22.0		620	**20.9**	**13264**	11800
3	3	98.6	11,800	8.3	595		3.1	1.3	19.2	2.5	19.9		620	**21.6**	**12302**	11600
4	3	98.8	10,400	8.2	555		3.3	1.0	18.9	1.9	18.7		620	**23.3**	**11622**	11100
5	3	99.0	8,720	8.2	514		3.5	0.7	18.9	1.4	17.6		620	**25.6**	**10529**	10300
6	3	99.1	7,200	8.0	474		3.6	0.5	18.5	0.9	16.3		620	**27.9**	**9414**	9300
7	3	99.4	5,300	8.0	433		3.9	0.3	18.5	0.5	15.4		620	**31.6**	**7592**	8200
SECOND RUN, PUMP #3 BETWEEN 14:52 AND 15:26																
27	3	96.7	14200	8.1	672		1.7	0.5	18.7	3.6	21.1		620	**18.0**	**13101**	12400
28	3	97.1	11800	8	596		2.1	0.4	18.5	2.5	19.3		620	**20.9**	**12275**	11850
29	3	97.5	8900	7.6	516		2.5	0.2	17.6	1.4	16.7		620	**24.1**	**10694**	10800
30	3	98	5230	7.5	432		3	0.1	17.3	0.5	14.9		620	**30.7**	**7506**	8500
FIRST RUN, PUMP #2 BETWEEN 14:01 AND 15:05																
8	2	97.2	13,000	7.6	645		1.68	1.6	17.6	3.0	20.5		620	**19.0**	**12506**	12350
9	2	97.2	11,800	7.6	607		1.71	1.3	17.6	2.5	19.7		620	**20.5**	**12045**	12000
10	2	97.3	10,200	7.5	559		1.82	1.0	17.3	1.9	18.4		620	**22.6**	**11313**	11400
11	2	97.5	8,300	7.4	510		2.01	0.7	17.1	1.2	17.0		620	**25.1**	**10084**	10550
12	2	97.7	6,156	7.4	458		2.19	0.4	17.1	0.7	16.0		620	**29.2**	**8326**	9150
13	2	97.9	3,750	7.4	408		2.43	0.1	17.1	0.3	15.1		620	**34.8**	**5699**	7000
14	2	97.1	12,700	8.3	642		1.59	1.5	19.1	2.9	21.9		620	**20.5**	**12269**	12000
PUMP #1 DATA CORRECTION																
21	1	97.8	3,850	9.3	1188		2.3	2.2	21.5	12.1	33.4		1150	**31.3**	**3727**	3097
22	1	97.1	3,700	9.6	1186		1.7	2.0	22.2	11.2	33.7		1150	**31.7**	**3588**	3066
23R	1	97.7	3,950	8.6	1186		2.3	2.3	19.9	12.8	32.6		1150	**30.7**	**3830**	3142
PUMP #4 DATA CORRECTION																
24	4	96.8	3,400	8.4	1187		1.5	1.7	19.4	9.5	29.1		1150	**27.3**	**3294**	3308
25	4	96.9	3,370	9.0	1187		1.6	1.7	20.8	9.3	30.1		1150	**28.3**	**3265**	3263
26	4	96.6	3,180	9.3	1186		1.3	1.5	21.5	8.3	30.0		1150	**28.2**	**3083**	3232

Figure 1: Kenmore Pump Station Pump Curve
1150 rpm, 1st Run, Pump #1



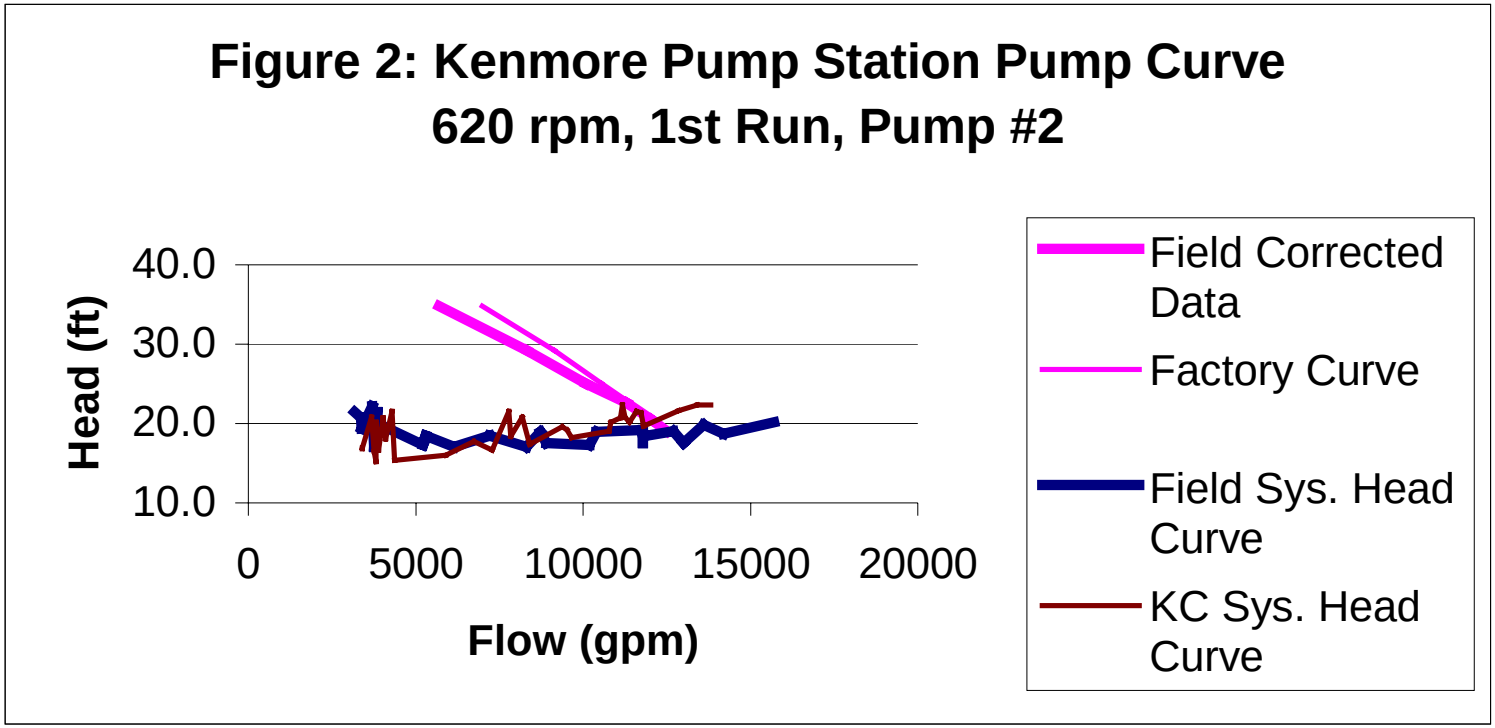
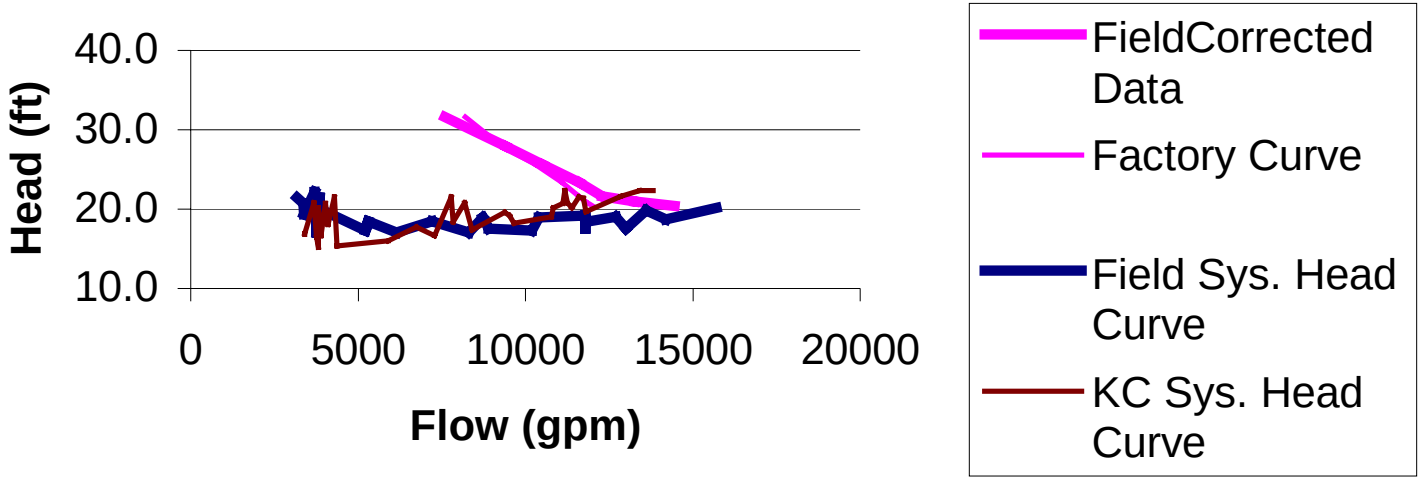


Figure 2: Kenmore Pump Station Pump Curve
620 rpm, 1st Run, Pump #2
Head (ft)
40.0
30.0
20.0
10.0
0
5000
10000
15000
20000
Flow (gpm)
Field Corrected Data
Factory Curve
Field Sys. Head Curve
KC Sys. Head Curve

Figure 3: Kenmore Pump Station Pump Curve
620 rpm, 1st Run, Pump #3



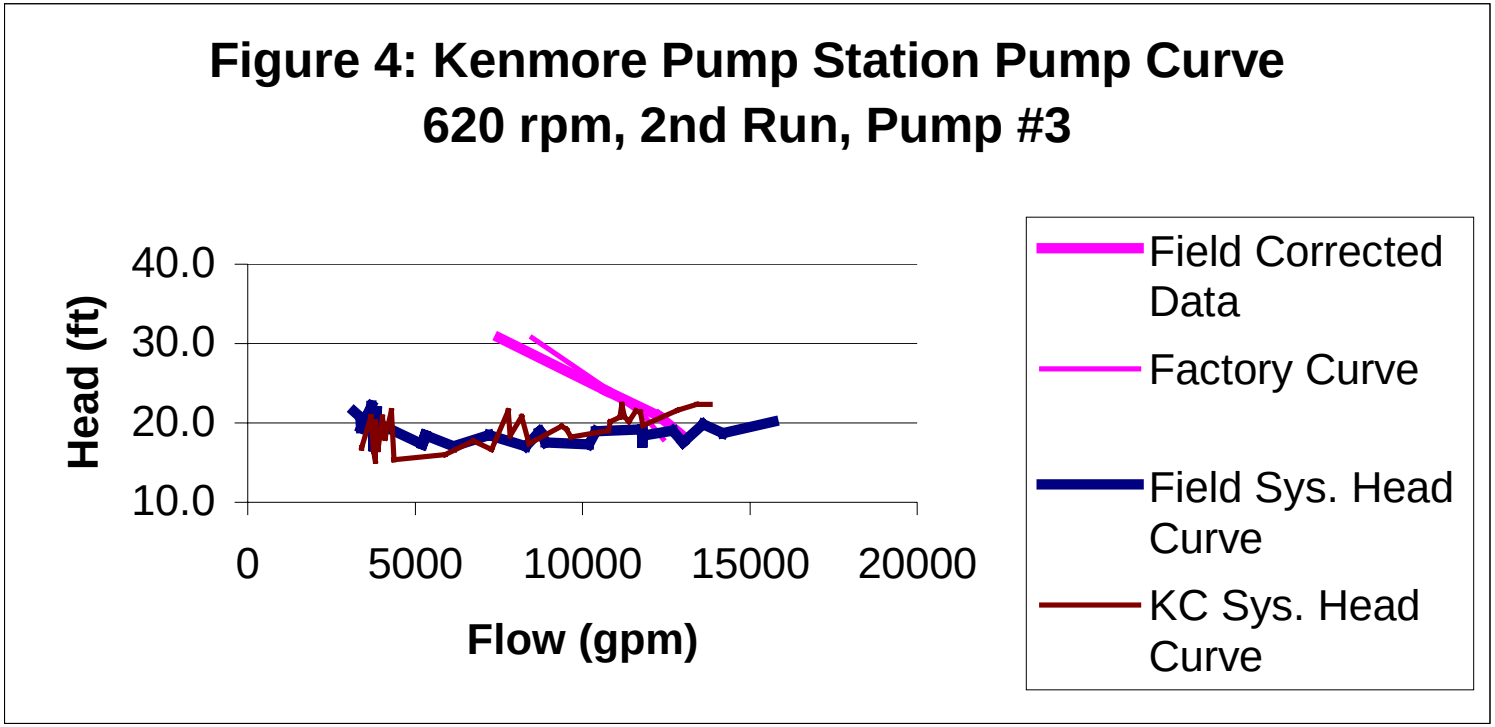
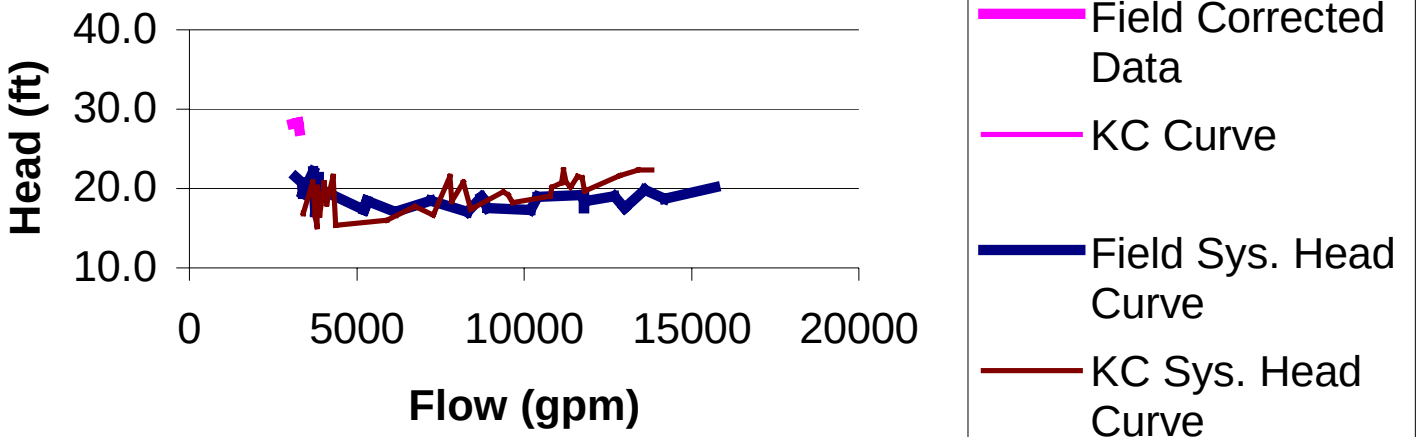


Figure 4: Kenmore Pump Station Pump Curve
620 rpm, 2nd Run, Pump #3
Head (ft)
40.0
30.0
20.0
10.0
0
5000
10000
15000
20000
Flow (gpm)
Field Corrected Data
Factory Curve
Field Sys. Head Curve
KC Sys. Head Curve

Figure 5: Kenmore Pump Station Pump Curve
1150 rpm, 1st Run, Pump #4



4.8 Kenmore Pump Station – Observations & Recommendations:

Summarized below are the observations and recommendations for the flow, wet well elevation, and speed measurement. According to the scope of work, an error range within 10% is considered acceptable according to the Hydraulics Institute for Field Testing.

4.8.1 Flow Measurement:

Control Panel Flow vs. Portable Meter Flow:

- Pump #1 – We were only able to get three points since this is a constant speed pump. This results in more erratic data plots. It appears the data from Run #23 was erroneous. The other data points were within 1%, which is well within the acceptable error range of 10%.

- Pump #2 – The control panel flow measures lower than the test meter flow. The average error between the control panel and test meter is 7%. This is within the 10% range making recalibration for the Pump #2 station flow meter unnecessary. However, the field data and factory curve closely match each other calling into question the in-station flow meter. It may be prudent to recalibrate the in-station meter although it is within 10 percent of the field data.

- Pump #3 – The control panel readings are below the test flow meter readings. The average error is 24%. Since the field data and factory curve match well, the Pump #3 station flow meter should be recalibrated and the flow transducers should be checked and replaced if necessary.

- Pump #4 – The control panel readings are above the test flow meter readings. The average error is 20%. The Pump #4 station flow meter should be recalibrated and the flow transducers should be checked and replaced if necessary.

Control Panel Flow vs. CATAD Flow Readings:

- Pump #1 – The average error between the control panel readings and the corresponding CATAD data readings were within 5% of each other. No recalibration of the station flow meter with the CATAD data system is necessary.

- Pump #2 – The average error between the control panel readings and the corresponding CATAD data readings was approximately 32%. The signal between the station flow meter and the CATAD system should be checked and recalibrated.

- Pump #3 – The average error between the control panel readings and the corresponding CATAD data readings was approximately 1.2%. The reason for the small average error is due to the fact that the error readings were evenly distributed both positive and negative. However, the data plot shows that the

readings are sporadic and do not show good correlation between the control panel flow data and the CATAD flow data. The signal between the station flow meter and the CATAD system should be checked and recalibrated.

- Pump #4 – The average error between the control panel readings and the corresponding CATAD data readings was less than one percent. None of the differences exceeded 8%. There appears to be good correlation and it appears that recalibration of the control panel flow meter and the CATAD data system is not necessary.

4.8.2 Speed Measurement

Control Panel Tachometer vs. Hand-Held Tachometer:

- Pump #1 – There is no control panel reading for speed on this pump since it is a constant speed pump.

- Pump #2 – The average error between the control panel readings and the hand-held tachometer readings was less than 2%. The control panel readings were consistently less than the hand-held tachometer readings. Due to the low percent error it is not necessary to recalibrate the control panel tachometer for Pump #2.

- Pump #3 – The average error between the control panel readings and the hand-held tachometer readings was less than 3%. The control panel readings were consistently less than the hand-held tachometer readings. Due to the low percent error it is not necessary to recalibrate the control panel tachometer for Pump #3.

- Pump #4 – There is no control panel reading for speed on this pump since it is a constant speed pump.

Control Panel RPM vs. CATAD RPM:

- Pump #1 – No control panel reading for speed.

- Pump #2 – The average error between the control panel speed and the CATAD data received was over 10%. Individual readings were off by as much as 58%. It is recommended the signal between the control panel rpm gauge and the CATAD data system be checked and recalibrated.

- Pump #3 – The average error between the control panel speed and the CATAD data received was approximately 12%. Individual readings were off by as much as 59%. It is recommended the signal between the control panel rpm gauge and the CATAD data system be checked and recalibrated.

- Pump #4 – No control panel reading for speed.

4.8.3 Wet Well Elevation Measurement

Control Panel Wet Well Elevation vs. CATAD Wet Well Elevation:

- The average error between the control panel wet well bubbler elevation and the CATAD data received was less than 1%. There is no need to check or calibrate the signal between the control panel wet well meter and the CATAD data system.

4.8.4 Pump Curves

Pump #1:

- The corrected flow data from the test runs were consistently higher than the corresponding points on the curve provided by King County.

Pump #2:

- The corrected data closely approximated the factory curve data.

Pump #3:

- The corrected data approximated the factory curve data.

Pump #4:

- The three points available to approximate a pump curve did not provide a smooth plot.

- The corrected data approximated the data provided by King County.

SECTION 5 WOODINVILLE PUMP STATION

5.1 Background

The Woodinville Pump Station is located along the Sammamish River, east of Lake Washington. The station receives flow from the Hollywood Pump Station through the Sammamish Valley Interceptor. This pump station also receives some local flow. The pump station pumps to the Bothell-Woodinville Interceptor where it flows by gravity to the Kenmore Pump Station. The interceptor flow switches to the York Pump Station approximately 6 months during the year.

5.2 Pump Station Design Information

Key design information for the Woodinville Pump Station is summarized in the table below.

Woodinville Pump Station Elevation Information (Metro Datum)

Pump Room Floor	103.75 ft
Wet Well Grating	114.00 ft
Motor Room Floor	117.00 ft
Overflow Elevation	117.00 ft
Control Room Floor	131.00 ft

Woodinville Pump Station Pump and Motor Information

Pumps #1, #2, and #3:	
Pump:	
Model:	Aurora Pump, Spher-Flow Model 612
Capacity:	6,110 gpm at 21.3 feet TDH at 822 rpm
Impeller Size:	15.0 to 17.63 inch diameter
Motor:	

Model:	Pump #1 & #2:Westinghouse, Life-Line, Model TWFC Pump #3: U.S. Electric, Model H22003
Rating:	Pump #1 & #2: 60 hp at 865 rpm, 230/460 V, 170/85 A, 3-phase. Pump #3: 100 hp
Speed Control	
Model:	Pumps #1 & #2: Flomatcher, model R2P4414, liquid rheostat, speed range 25 to 95 percent of motor rated speed. Pump #3: Variable Frequency Drive. Robicon model 454GT

5.3 Key Points and Issues

There were several key points and issues discovered during the testing and data analysis of the Woodinville Pump Station. They are summarized below:

- A single manufacturer's pump curve was provided for all three pumps. This curve was used for the pumps at the Woodinville and Hollywood Pump Stations. There are no pump-specific curves for the pumps at these stations.
- The motor and speed controller on Pump #3 have recently been replaced. The new speed controller is a VFD rather than a liquid rheostat. The VFD speed control is more precise and responds quicker than the liquid rheostat speed controller.
- The speed settings for the VFD seemed steadier during the test runs than the speed settings for the liquid rheostat controlled pumps. The liquid rheostats provided a very sluggish control (the time difference from when the speed setting is changed to when the pump speed changes and settles down is substantial). This will cause difficulty when trying to establish a correlation with treatment plant CATAD data since this data will record a scan when there is a substantial difference in pump conditions.

5.4 Measuring Equipment Setup at Woodinville Pump Station

On the pump floor, a pressure gauge was installed on the pump discharge. The tap was located on the edge of the discharge flange. A strap-on flow meter was positioned on the force main above the sleeve for the Flomatcher system and below the "D" coupling. The meter installation required paint to be chipped from the force main and a thickness

measurement of the pipe wall where the flow transducers were mounted was taken using an ultrasonic thickness gage. Figure DIA – 2 in the Appendix is a schematic diagram of the piping and approximate equipment locations.

Pressure gauge readings were read directly and hand recorded. The elevation from the centerline of the volute to the pump floor was measured to correct the pressure gauge reading. The discharge pressure was used to calculate total dynamic head.

The wet well level was recorded for each pump run from the control panel. The wet well level bubbler was checked by measuring the distance to the water surface from the grate. When the elevation was calculated using the grate elevation from the record drawings, it checked with the control panel elevation within 0.85 feet. (Panel reading was higher than field measurement). This error in bubbler elevation was not corrected since it is uncertain if the bubbler was in error or if the datum used to check the bubbler was in error.

No Data logger was used.

Calibration stickers were found for the station's ultrasonic flow meters. They were dated 12-2-96 with initials "JB".

5.5 Measuring Protocol at Woodinville Pump Station

5.5.1 Testing Sequence

The pumps were tested in a single day (November 8, 1999). Pump #2 was tested first at several speeds and in tandem with Pump #3. This was done to get several points along the system head curve. Pump #1 was tested at several speeds and one trial was run with Pump #3. Pump #3 was tested alone at several speeds.

5.5.2 Measuring Protocol – Pump Floor

Data were read on the pump floor as follows:

- Flow: the pump flow was read directly from the Panametrics flow meter data display and hand recorded.
- Pressure: the discharge pressure from the pump was read directly from the dial gauge and hand recorded.
- Pump Speed: the pump speed was read from the drive shaft using the hand-held tachometer.
- Time: the time of the reading was taken from a wristwatch that was compared to the control panel clock.

5.5.3 Measuring Protocol – Main Control Room

Data were read in the main control room as follows:

- Flow: the total station flow and individual pump flow were read directly from the control panel.
- Pressure: no discharge pressure reading was available on the main control panel.
- Wet Well Elevation: the wet well elevation was read from the control panel at the time of the pump run.
- Pump Speed: the pump speed was read directly from the control panel at the time of the pump run. The pumps were run at different speeds to obtain a spread of points on the system head curve.
- Motor Operating Amps: the operating amps of the pump motor were recorded for reference for each pump run.
- Time: the time of the reading was read from the control panel.

5.5.4 Woodinville Pump Station: Collected Data

This section presents and compares the data collected at the Woodinville Pump Station. Data were collected on the pump floor using portable measuring devices, at the control panel, and from the CATAD system.

Table 5 presents the hand recorded data taken on November 8th. Table 6 summarizes the differences between the hand recorded data on the pump floor and the corresponding data recorded in the control room. This gives an indication of the error present between the control panel readings and the data readings from the portable measuring devices.

Table 7 summarizes and compares the pump station data and CATAD data. The table compares pump-on time, wet well elevation, pump flow, and pump speed.

Figures A-14 through A-26 in the Appendix graph the data collected at the pump floor, control panel, and CATAD system. If the data matched exactly, it would plot along a 1:1 slope on the graph. These plots show how the data compare.

Table 5: Woodinville Pump Station Recorded Data

Run #	Date	Time (Main Floor)	Pump #	Wet Well Elev. (ft)	Amps	Control Panel Flow Station Total (MGD)	*Control Panel Flow Station Total (gpm) (Calculated)*	Control Panel Flow Indiv. Pump (MGD)	*Control Panel Flow Indiv. Pump (gpm) (Calculated)*	Speed (rpm)	Time (Pump Floor)	Test Meter Flow (gpm)	Observed Flow Variance (gpm)	Pressure Gage (psi)	*Pressure (ft)*	Hand-Held Tachometer (rpm)
01	11/8/99	10:39	2	111.9	68.5	5.82	*4,042*	No Reading	*No Reading*	600	9:47	4,580	50	7.00	*16.2*	558.8
01R	11/8/99	11:05	2&3	111.1	65.0	13.40	*9,306*	5.60	*3,889*	595	10:14	4,340	20	7.25	*16.7*	590.0
02	11/8/99	10:51	2	112.7	62.0	4.97	*3,451*	No Reading	*No Reading*	545	10:00	4,010	20	7.00	*16.2*	538.5
03	11/8/99	11:32	2&3	110.5	60.0	12.06	*8,375*	4.40	*3,056*	536	10:41	3,330	20	7.20	*16.6*	528.0
04	11/8/99	11:40	2&3	110.5	54.0	11.02	*7,653*	3.20	*2,222*	467	10:49	2,740	20	7.00	*16.2*	461.9
05	11/8/99	11:52	2&3	110.8	51.0	9.43	*6,549*	1.70	*1,181*	407	11:00	1,230	20	6.80	*15.7*	402.2
06	11/8/99	12:46	1	111.2	58.0	3.73	*2,590*	3.70	*2,569*	549	11:54	2,940	10	6.50	*15.0*	538.6
07	11/8/99	12:57	1	111.9	64.0	5.35	*3,715*	5.30	*3,681*	627	12:05	3,860	10	6.80	*15.7*	617.4
08	11/8/99	13:04	1	111.8	73.0	7.33	*5,090*	7.30	*5,069*	741	12:12	5,450	20	6.50	*15.0*	730.0
09	11/8/99	13:12	1	111.8	80.5	8.66	*6,014*	8.60	*5,972*	804	12:21	6,350	80	4.00	*9.2*	793.2
10	11/8/99	13:24	1	112.3	54.0	0.54	*375*	0.50	*347*	407	12:32	650	50	6.60	*15.2*	398.1
11	11/8/99	13:36	1&3	112.0	56.0	12.50	*8,681*	2.50	*1,736*	489	12:42	1,280	20	7.00	*16.2*	479.0
11a	11/8/99										12:45	1,900	20	7.00	*16.2*	479.0
12	11/8/99	15:05	3	111.2	70.0	9.70	*6,736*	9.80	*6,806*	837	14:13	6,890	20	9.60	*22.2*	848.9
12a											14:14	6,840	10	9.60	*22.2*	848.9
13	11/8/99	15:14	3	111.7	56.0	8.66	*6,014*	8.70	*6,042*	770	14:22	6,310	50	9.40	*21.7*	780.7
14	11/8/99	15:22	3	111.9	44.0	7.76	*5,389*	7.80	*5,417*	710	14:30	5,600	100	8.90	*20.5*	719.5
15	11/8/99	15:31	3	111.7	35.0	6.33	*4,396*	6.40	*4,444*	650	14:39	4,480	20	8.50	*19.6*	657.8
15a											14:40	4,610	50	8.50	*19.6*	657.8
16	11/8/99	15:40	3	111.7	27.0	5.28	*3,667*	5.40	*3,750*	591	14:49	3,800	20	8.10	*18.7*	598.1
16a											14:50	3,900	30	8.10	*18.7*	598.1
17	11/8/99	15:49	3	111.7	22.0	4.14	*2,875*	4.30	*2,986*	530	14:57	3,000	30	7.60	*17.5*	537.8
18	11/8/99	15:55	3	111.9	16.0	2.97	*2,063*	3.00	*2,083*	470	15:03	2,140	30	7.25	*16.7*	476.0
19	11/8/99	16:03	3	112.0	12.0	1.70	*1,181*	1.80	*1,250*	420	15:12	1,280	50	7.00	*16.2*	425.5

Note: Columns in Italics are calculated and were not recorded in the field

Table 6: Woodinville Pump Station Summary of Errors Between Pump Floor and Control Room Data Readings

Run #	Date	Pump #	Control Panel Flow Station Total (MGD)	*Control Panel Flow Station Total (gpm) (Calculated)*	Control Panel Flow Indiv.Pump (MGD)	*Control Panel Flow Indiv. Pump (gpm) (Calculated)*	Test Meter Flow (gpm)	Flow Variance	Flow Difference (gpm)	% Difference Meter to Control Panel	% Difference Variance to Control Panel	Control Panel Speed (rpm)	Hand-Held Tach (rpm)	Speed Difference (rpm)	% Difference Tachometer to Control Panel
01	11/8/99	2	5.82	*4,042*	No Reading	*No Reading*	4,580	50	-538	-13.3%	1.2%	600	558.8	41.2	6.9%
01R	11/8/99	2&3	13.40	*9,306*	5.60	*3,889*	4,340	20	-451	-4.8%	0.2%	595	590.0	5.0	0.8%
02	11/8/99	2	4.97	*3,451*	No Reading	*No Reading*	4,010	20	-559	-16.2%	0.6%	545	538.5	6.5	1.2%
03	11/8/99	2&3	12.06	*8,375*	4.40	*3,056*	3,330	20	-274	-3.3%	0.2%	536	528.0	8.0	1.5%
04	11/8/99	2&3	11.02	*7,653*	3.20	*2,222*	2,740	20	-518	-6.8%	0.3%	467	461.9	5.1	1.1%
05	11/8/99	2&3	9.43	*6,549*	1.70	*1,181*	1,230	20	-49	-0.8%	0.3%	407	402.2	4.8	1.2%
06	11/8/99	1	3.73	*2,590*	3.70	*2,569*	2,940	10	-371	-14.3%	0.4%	549	538.6	10.4	1.9%
07	11/8/99	1	5.35	*3,715*	5.30	*3,681*	3,860	10	-179	-4.8%	0.3%	627	617.4	9.6	1.5%
08	11/8/99	1	7.33	*5,090*	7.30	*5,069*	5,450	20	-381	-7.5%	0.4%	741	730.0	11.0	1.5%
09	11/8/99	1	8.66	*6,014*	8.60	*5,972*	6,350	80	-378	-6.3%	1.3%	804	793.2	10.8	1.3%
10	11/8/99	1	0.54	*375*	0.50	*347*	650	50	-303	-80.7%	13.3%	407	398.1	8.9	2.2%
11	11/8/99	1&3	12.50	*8,681*	2.50	*1,736*	1,280	20	456	5.3%	0.2%	489	479.0	10.0	2.0%
11a	11/8/99			*0*			1,900	20	na	na	na	na	479.0	na	na
12	11/8/99	3	9.70	*6,736*	9.80	*6,806*	6,890	20	-84	-1.3%	0.3%	837	848.9	-11.9	-1.4%
12a				*0*			6,840	10	na	na	na	na	848.9	na	na
13	11/8/99	3	8.66	*6,014*	8.70	*6,042*	6,310	50	-268	-4.5%	0.8%	770	780.7	-10.7	-1.4%
14	11/8/99	3	7.76	*5,389*	7.80	*5,417*	5,600	100	-183	-3.4%	1.9%	710	719.5	-9.5	-1.3%
15	11/8/99	3	6.33	*4,396*	6.40	*4,444*	4,480	20	-36	-0.8%	0.5%	650	657.8	-7.8	-1.2%
15a				*0*			4,610	50	na	na	na	na	657.8	na	na
16	11/8/99	3	5.28	*3,667*	5.40	*3,750*	3,800	20	-50	-1.4%	0.5%	591	598.1	-7.1	-1.2%
16a				*0*			3,900	30	na	na	na	na	598.1	na	na
17	11/8/99	3	4.14	*2,875*	4.30	*2,986*	3,000	30	-14	-0.5%	1.0%	530	537.8	-7.8	-1.5%
18	11/8/99	3	2.97	*2,063*	3.00	*2,083*	2,140	30	-57	-2.7%	1.5%	470	476.0	-6.0	-1.3%
19	11/8/99	3	1.70	*1,181*	1.80	*1,250*	1,280	50	-30	-2.5%	4.2%	420	425.5	-5.5	-1.3%

Note: Columns in Italics are calculated and were not recorded in the field

Table 7: Woodinville Pump Station Summary of Errors Between Pump Station Data and CATAD Data

Run #	Date	Time Control Panel	Time Pump Floor	Pump On CATAD	Pump #	Control Panel Wet Well El.	CATAD Wet Well El.	% Diff. Control Panel to CATAD	Control Panel Station Flow (mgd)	CATAD Station Flow (mgd)	% Diff. Control Panel to CATAD	Control Panel Pump Flow (mgd)	Portable Flow Meter Pump (mgd)	CATAD Flow Pump (mgd)	% Diff. Control Panel to CATAD	% Diff. Portable Meter to CATAD	Control Panel (rpm)	Tach. (rpm)	CATAD (rpm)	% Diff. Control Panel to CATAD	% Diff. Tach. to CATAD
01R	11/8/99	11:05	10:14	10:10	2&3	111.1	111.09	-0.01%	13.40	6.91	-93.92%	5.60	6.25	5.33	-5.07%	-17.25%	595	590.0	616.3	3.45%	4.26%
02	11/8/99	10:51	10:00	9:56	2	112.7	112.69	-0.01%	4.97	5.69	12.65%	N R	5.77	5.84	n/a	1.12%	545	538.5	569.8	4.35%	5.49%
03	11/8/99	11:32	10:41	10:38	2&3	110.5	110.37	-0.12%	12.06	12.3	1.95%	4.40	4.80	4.32	-1.85%	-11.00%	536	528.0	540.5	0.82%	2.30%
04	11/8/99	11:40	10:49	10:45	2&3	110.5	110.54	0.04%	11.02	11.24	1.96%	3.20	3.95	3.55	9.86%	-11.14%	467	461.9	496.2	5.88%	6.91%
05	11/8/99	11:52	11:00	10:56	2&3	110.8	110.84	0.04%	9.43	9.03	-4.43%	1.70	1.77	1.27	-33.86%	-39.46%	407	402.2	406.2	-0.19%	0.99%
06	11/8/99	12:46	11:54	11:51	1	111.2	111.10	-0.09%	3.73	4.54	17.84%	3.70	4.23	4.28	13.55%	1.08%	549	538.6	566.0	3.01%	4.85%
07	11/8/99	12:57	12:05	12:02	1	111.9	111.82	-0.07%	5.35	5.04	-6.15%	5.30	5.56	5.39	1.67%	-3.12%	627	617.4	622.4	-0.73%	0.81%
08	11/8/99	13:04	12:12	12:09	1	111.8	111.81	0.01%	7.33	7.65	4.18%	7.30	7.85	7.51	2.80%	-4.50%	741	730.0	733.0	-1.09%	0.41%
09	11/8/99	13:12	12:21	12:18	1	111.8	111.86	0.05%	8.66	8.72	0.69%	8.60	9.14	8.86	2.93%	-3.21%	804	793.2	800.5	-0.43%	0.92%
10	11/8/99	13:24	12:32	12:29	1	112.3	112.22	-0.07%	0.54	1.19	54.62%	0.50	0.94	0.04	-1150.00%	-2240.00%	407	398.1	410.9	0.95%	3.12%
11	11/8/99	13:36	12:42	12:42	1&3	112.0	111.92	-0.07%	12.50	11.97	-4.43%	2.50	1.84	2.79	10.39%	33.94%	489	479.0	491.8	0.56%	2.59%
11a	11/8/99	13:36	12:45	12:42	1&3	112.0	111.92	-0.07%	12.50	11.97	-4.43%	2.50	2.74	2.79	10.39%	1.94%	489	479.0	491.8	0.56%	2.59%
12	11/8/99	15:05	14:13	14:11	3	111.2	111.19	-0.01%	9.70	9.36	-3.63%	9.80	9.92	9.80	0.00%	-1.24%	837	848.9	846.3	1.10%	-0.30%
12a	11/8/99	15:05	14:14	14:11	3	111.2	111.19	-0.01%	9.70	9.36	-3.63%	9.80	9.85	9.80	0.00%	-0.51%	837	848.9	846.3	1.10%	-0.30%
13	11/8/99	15:14	14:22	14:20	3	111.7	111.84	0.13%	8.66	14.26	39.27%	8.70	9.09	8.76	0.68%	-3.73%	770	780.7	780.2	1.30%	-0.07%
14	11/8/99	15:22	14:30	14:28	3	111.9	111.93	0.03%	7.76	7.46	-4.02%	7.80	8.06	7.57	-3.04%	-6.53%	710	719.5	719.2	1.28%	-0.04%
15	11/8/99	15:31	14:39	14:37	3	111.7	111.74	0.04%	6.33	6.39	0.94%	6.40	6.45	6.41	0.16%	-0.64%	650	657.8	657.5	1.13%	-0.05%
15a	11/8/99	15:31	14:40	14:37	3	111.7	111.74	0.04%	6.33	6.39	0.94%	6.40	6.64	6.41	0.16%	-3.56%	650	657.8	657.5	1.13%	-0.05%
16	11/8/99	15:40	14:49	14:46	3	111.7	111.73	0.03%	5.28	14.65	63.96%	5.40	5.47	5.34	-1.12%	-2.47%	591	598.1	598.7	1.29%	0.10%
16a	11/8/99	15:40	14:50	14:46	3	111.7	111.73	0.03%	5.28	14.65	63.96%	5.40	5.62	5.34	-1.12%	-5.17%	591	598.1	598.7	1.29%	0.10%
17	11/8/99	15:49	14:57	14:54	3	111.7	111.74	0.04%	4.14	4.11	-0.73%	4.30	4.32	4.24	-1.42%	-1.89%	530	537.8	538.0	1.48%	0.03%
18	11/8/99	15:55	15:03	15:00	3	111.9	111.88	-0.02%	2.97	2.79	-6.45%	3.00	3.08	3.05	1.64%	-1.04%	470	476.0	477.5	1.57%	0.31%
19	11/8/99	16:03	15:12	15:09	3	112.0	112.22	0.20%	1.70	1.73	1.73%	1.80	1.84	1.93	6.74%	4.50%	420	425.5	426.1	1.44%	0.15%

5.6 Woodinville Pump Station – Data Analysis

The data collected during the pump runs was analyzed and corrected in order to develop pump curves. These pump curves were compared to manufacturer's pump curves and/or pump data provided by the County.

The pump data were corrected by using the pump affinity laws. These laws are used to convert/correct flow and pressure data collected at a given pump speed to a set curve speed. This is done by multiplying the square of the ratio of curve speed to pump speed to correct for head, and multiplying the ratio of curve speed to pump speed to correct for flow.

The total differential head is calculated by adding the discharge head, velocity head, and suction head; and subtracting from this total the inlet head. The suction head for the pump station is calculated by adding the minor losses and friction losses of the inlet piping. This is calculated from each pump run based upon the measured flow.

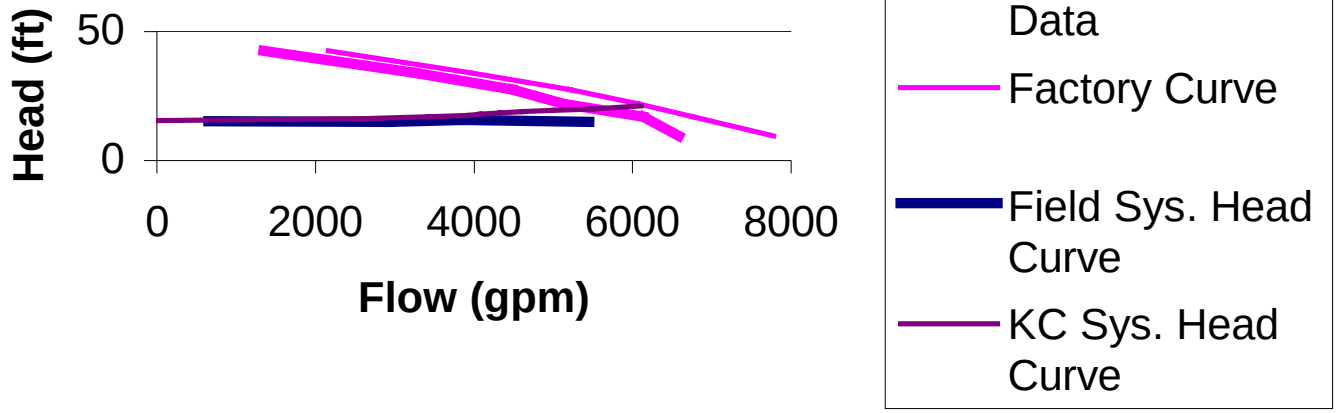
Table 8 summarizes the data correction calculations and shows the corrected pump data. All pumps have been corrected to a pump speed of 822 rpm. This speed is within the optimal operating range for the pumps.

Figures 6 through 8 are plots of the corrected pump curves. Also shown on each figure is the factory curve generated from data provided by the pump manufacturer and/or the County's modeling database.

Table 8: Woodinville Pump Station – Table of Corrected Pump Data

						P #1	P #2	P #3						
		ELEVATION OF PUMP CENTER LINE				107	107	107						
		DISCH. GAGE HEIGHT				107	107	107						
		FIELD DATA				**CORRECTED DATA**					CORRECTED			FLOW FROM
RUN	PUMP	BUBBLER	TEST METER	DISC. PRESS.	SPEED	INLET	SUCTION	DISCH. HEAD	VELOCITY	TEST TOTAL	CURVE			FACTORY
NO.	NO.	LEVEL (ft)	FLOW (gpm)	(psi)	RPM	HEAD	HEAD	(ft)	HEAD LOSS	HEAD	RPM	HEAD	FLOW	CURVE
FIRST RUN. PUMP #2 BETWEEN 10:39 AND 11:52														
1	2	111.9	4,580	7.00	559	4.9	0.6	16.2	1.6	13.6	822	**29.3**	**6737**	4930
01R	2&3	111.1	4,340	7.3	590	4.1	0.6	16.7	1.5	14.7	822	**28.5**	**6047**	5000
02	2	112.7	4,010	7.0	539	5.7	0.5	16.2	1.3	12.2	822	**28.5**	**6121**	5000
03	2&3	110.5	3,330	7.2	528	3.5	0.3	16.6	0.9	14.3	822	**34.8**	**5184**	3835
04	2&3	110.5	2,740	7.0	462	3.5	0.2	16.2	0.6	13.5	822	**42.7**	**4876**	2160
05	2&3	110.8	1,230	6.8	402	3.8	0.05	15.7	0.1	12.1	822	**50.4**	**2514**	640
SECOND RUN, PUMP #1 BETWEEN 12:46 AND 13:36														
06	1	111.2	2,940	6.5	539	4.2	0.3	15.0	0.7	11.8	822	**27.4**	**4487**	5210
07	1	111.9	3,860	6.80	617.4	4.9	0.5	15.7	1.2	12.4	822	**22.0**	**5139**	6080
08	1	111.8	5,450	6.50	730	4.8	0.9	15.0	2.3	13.5	822	**17.1**	**6137**	6760
09	1	111.8	6,350	4.00	793.2	4.8	1.2	9.2	3.2	8.8	822	**9.5**	**6581**	7780
10	1	112.3	650	6.60	398.1	5.3	0.01	15.2	0.0	10.0	822	**42.6**	**1342**	2165
11a	1&3	112.0	1,900	7.00	479	5	0.11	16.2	0.3	11.6	822	**34.1**	**3261**	3960
THIRD RUN, PUMP #3 BETWEEN 15:05 AND 16:03														
12a	3	111.2	6,840	9.6	849	4.2	1.4	22.2	3.7	23.1	822	**21.6**	**6623**	6120
13	3	111.7	6,310	9.4	781	4.7	1.2	21.7	3.1	21.3	822	**23.7**	**6644**	5800
14	3	111.9	5,600	8.9	720	4.9	1.0	20.6	2.5	19.1	822	**24.9**	**6398**	5600
15a	3	111.7	4,610	8.5	658	4.7	0.6	19.6	1.7	17.3	822	**26.9**	**5761**	5280
16a	3	111.7	3,900	8.1	598	4.7	0.5	18.7	1.2	15.7	822	**29.6**	**5360**	4840
17	3	111.7	3,000	7.6	538	4.7	0.3	17.6	0.7	13.8	822	**32.3**	**4585**	4360
18	3	111.9	2,140	7.3	476	4.9	0.1	16.7	0.4	12.4	822	**36.8**	**3696**	3320
19	3	112.0	1,280	7.00	425.5	5.0	0.05	16.2	0.1	11.4	822	**42.4**	**2473**	2160

Figure 6: Woodinville Pump Station Pump Curve · Pump #1



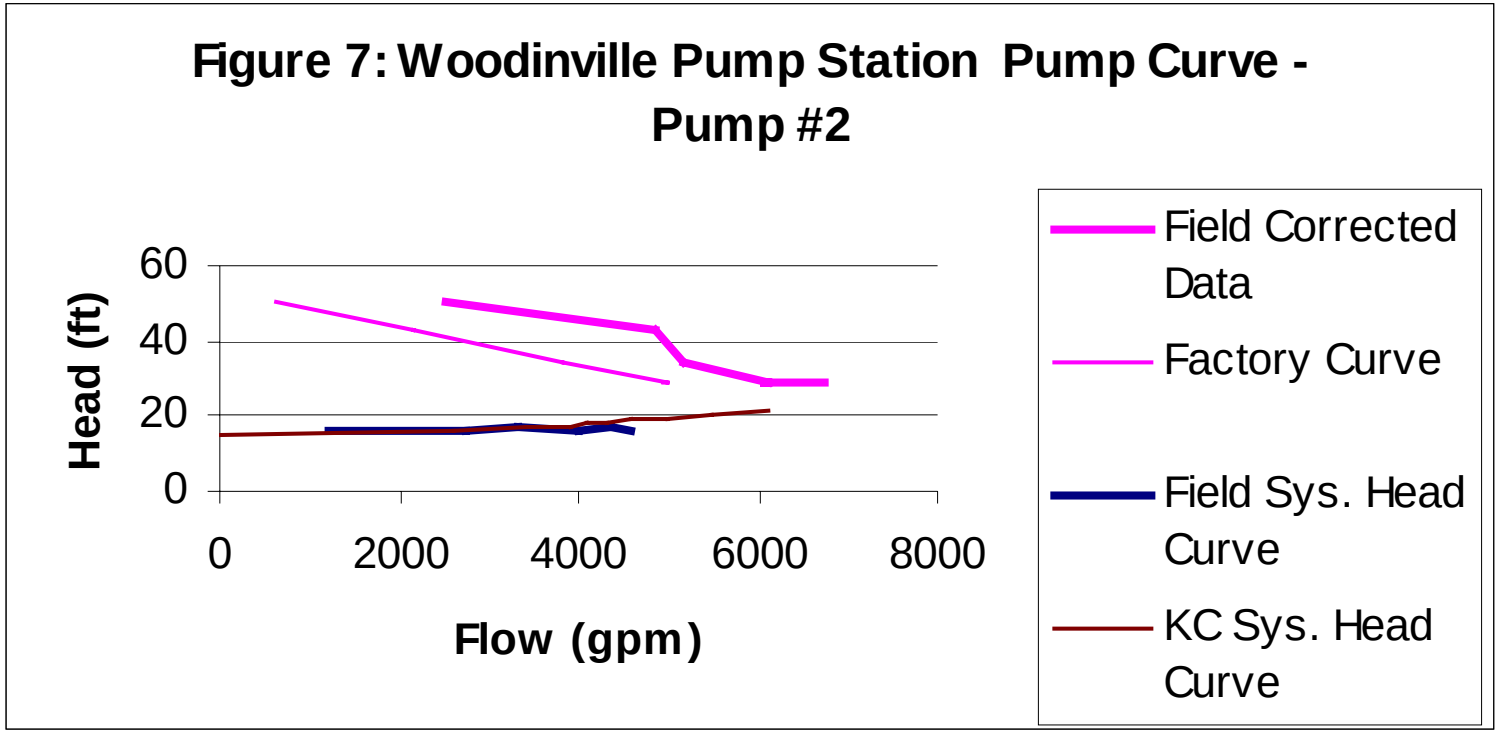
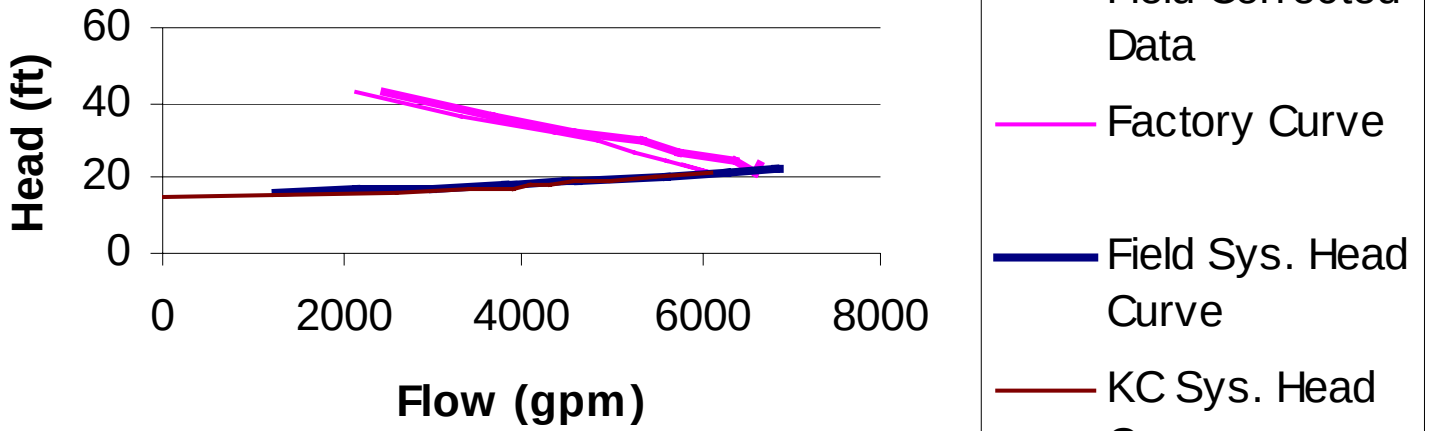


Figure 7: Woodinville Pump Station Pump Curve - Pump #2
Head (ft)
60
40
20
0
0
2000
4000
6000
8000
Flow (gpm)
Field Corrected Data
Factory Curve
Field Sys. Head Curve
KC Sys. Head Curve

Figure 8: Woodinville Pump Station Pump Curve - Pump #3



5.7 Woodinville Pump Station – Observations & Recommendations:

Summarized below are the observations and recommendations for the flow, wet well elevation, and speed measurement. According to the scope of work, an error range within 10% is considered acceptable according to the Hydraulics Institute for Field Testing.

5.7.1 Flow Measurement:

Control Panel Flow vs. Portable Meter Flow:

- Pump #1 – The data collected on the test runs did not show good correlation between the pump flow recorded from the portable meter and the control panel flow. Two of the five points are somewhat correlated but the remaining three are not. The Pump #1 station flow meter should be checked and recalibrated.
- Pump #2 – The control panel flow and test meter flow show good correlation for all data points except one. The average error between the control panel and test meter is 7.5%. This is within the 10% range making recalibration for the Pump #2 station flow meter unnecessary.
- Pump #3 – The control panel readings test flow meters readings show good correlation. The average error is 2.25%. This is within the 10% range making recalibration for Pump #3 station flow meter unnecessary.

Control Panel Flow vs. CATAD Flow Readings:

- Pump #1 – The data readings for the control panel flow and CATAD flow show good correlation. The error on the low flow reading was higher than the typical error within the mid-range of the test data. The average error between the control panel readings and the corresponding CATAD data readings were 23% including the low flow data point. The average error excluding the low flow data point is 5.82%. The County may want to check the calibration between the Pump #1 control panel flow meter and the CATAD system, but it appears that there is good correlation within the typical operating range for the Pump #1 flow meter.
- Pump #2 – There appears to be good correlation between the control panel readings and the CATAD system for Pump #2. The average error between the control panel readings and the corresponding CATAD data readings was approximately 10%. The higher error readings are within the low flow readings. The County may want to check the calibration between the Pump #2 control panel flow meter and the CATAD system, but it appears that there is good correlation within the typical operating range for the Pump #2 flow meter.
- Pump #3 – There is good correlation between the Pump #3 control panel flow readings and the CATAD system. The average error between the control panel readings and the corresponding CATAD data readings was approximately 1%. There is no need to recalibrate the signal between the Pump #3 flow meter and the CATAD system.

5.7.2 Speed Measurement

Control Panel Tachometer vs. Hand-Held Tachometer:

- Pump #1 – There is good correlation between the Pump #1 control panel speed reading and the tachometer readings taken on the pump floor. The average error between the readings was approximately 1.7%. There is no need to recalibrate the Pump #1 speed meter on the Control Panel.
- Pump #2 – There is good correlation between the Pump #2 control panel speed readings and the tachometer readings taken on the pump floor. The average error between the control panel readings and the hand-held tachometer readings was approximately 2%. Due to the low percent error it is not necessary to recalibrate the control panel tachometer for Pump #2.
- Pump #3 – The control panel speed readings and the tachometer readings for Pump #3 show good correlation. The average error between the control panel readings and the hand-held tachometer readings approximately 1.3%. Due to the low percent error it is not necessary to recalibrate the control panel tachometer for Pump #3.

Control Panel RPM vs. CATAD RPM:

- Pump #1 – The data between the Pump #1 control panel speed and the CATAD system show good correlation. The average error between the readings is less than 1%. There is no need to check or calibrate the pump speed signal to the CATAD system for Pump #1.
- Pump #2 – There is good correlation between the Pump #2 control panel speed and the CATAD system reading. The average error between readings is approximately 3%. There is no need to check or calibrate the pump speed signal to the CATAD system for Pump #2.
- Pump #3 – There is good correlation between the Pump #3 control panel speed and the CATAD system reading. The average error between readings is approximately 1%. There is no need to check or calibrate the pump speed signal to the CATAD system for Pump #3.

5.7.3 Wet Well Elevation Measurement

Control Panel Wet Well Elevation vs. CATAD Wet Well Elevation:

- The control panel elevation and the field check of the wet well elevation differed by 0.85 feet. (Panel reading was higher than field measurement). Check and recalibrate the wet well bubbler.
- The plot of the control panel wet well elevation and the CATAD wet well readings show good correlation. The average error between the control panel wet well bubbler elevation and the CATAD data received was less than 1%. There is no need to check or calibrate the signal between the control panel wet well meter and the CATAD data system.

5.7.4 Pump Curves

Pump #1:

- The corrected flow data from the test runs were consistently lower than the corresponding points on the factory curve. The plot of the curves did follow the same approximate slope and shape. The same basic shape indicates the field data from the flow meter is believable.

Pump #2:

- The corrected flow data from the test runs made an erratic plot. The corrected data were consistently higher than the factory curve. The reason for the erratic plot could be due to the fact that most of Pump #2 test runs were performed in tandem with Pump #3. This may have caused additional turbulence and influenced the quality of the data.

Pump #3:

- The corrected flow data from the test runs and the factory curve data showed a high degree of correlation. The corrected data plotted consistently higher than the factory curve data. The slope and shape of the plots were approximately the same. The same basic shape indicates the field data from the flow meter is believable.

SECTION 6 HOLLYWOOD PUMP STATION

6.1 Background

The Hollywood Pump Station is located along the Sammamish River, east of Lake Washington. The station receives flow from the NE Lake Sammamish Interceptor and pumps wastewater to the Sammamish Valley Interceptor. It then flows by gravity to the Woodinville Pump Station. If the pump station is shut down, wastewater flows to the York Pump Station, which conveys the flow to the East Side Interceptor.

6.2 Pump Station Design Information

Key design information for the Hollywood Pump Station is summarized in the table below.

Hollywood Pump Station Elevation Information (Metro Datum)

Pump Room Floor	101.00 ft
Wet Well Grating	112.50 ft
Motor Room Floor	116.33 ft
Overflow Elevation	124.20 ft
Control Room Floor	131.00 ft

Hollywood Pump Station Pump and Motor Information

Pumps #1, #2, and #3:	
Pump:	
Model:	Aurora Pump, Spher-Flow Model 612
Capacity:	5,000 gpm at 23.5 feet TDH at 822 rpm
Impeller Size:	15.0 to 17.25 inch diameter
Motor:	
Model:	Pump #1, #2 & #3:Westinghouse, Life-Line, Model TWFC

Rating:	Pump #1, #2 & #3: 60 hp at 865 rpm, 230/460 V, 170/85 A, 3-phase.
Speed Control	
Model:	Pumps #1, #2 & #3: Flomatcher, model R2P4414, liquid rheostat, speed range 25 to 95 percent of motor rated speed.

6.3 Key Points and Issues

There were several key points and issues discovered during the testing and data analysis of the Hollywood Pump Station. They are summarized below:

- A single manufacturer's pump curve was provided for all three pumps. This curve was used for the pumps for the Hollywood and Woodinville Pump Stations. There are no pump-specific curves for the pumps at these stations.
- The liquid rheostats provided a very sluggish control (the time difference from when the speed setting is changed to when the pump speed changes and settles down can be over several minutes). This will cause difficulty when trying to establish a correlation with treatment plant CATAD data since this data will record a scan when there is a substantial difference in pump conditions (i.e.) the CATAD system will record a scan before the pump has completely settled down to its operating point.
- The inflow rate into the wet well was low. It was difficult to get steady readings since there was not much time to let the speed setting settle in. Additionally, the wet well elevation would change during the test since the inflow rate could not keep up with the pump's discharge rate.

6.4 Measuring Equipment Setup at Hollywood Pump Station

On the pump floor, a pressure gauge (NBS traceable) was installed on the pump discharge. The tap was located on the edge of the discharge flange. A strap-on flow meter was positioned on the force main above the sleeve for the Flomatcher system and below the "D" coupling. The meter installation required paint to be chipped from the force main and a thickness measurement of the pipe wall where the flow transducers were mounted was taken using an ultrasonic thickness gage. Figure DIA – 3 in the Appendix is a schematic diagram of the piping and approximate equipment locations.

Pressure gauge readings were read directly and hand recorded. The elevation from the centerline of the volute to the pump floor was measured to correct the pressure gauge reading. The discharge pressure was used to calculate total dynamic head.

The wet well level was recorded for each pump run from the control panel. The wet well level bubbler was checked by measuring the distance to the water surface from the grate. When the elevation was calculated using the grate elevation from the record drawings, it checked with the control panel elevation within 0.18 feet. (The panel reading was lower than the field measurement).

No data logger was used.

No calibration stickers were found.

6.5 Measuring Protocol at Hollywood Pump Station

6.5.1 Testing Sequence

The pumps were tested in a single day (November 9, 1999). Pump #3 was tested first at several speeds. This was done to get several points along the system head curve. Pump #2 was then tested at several speeds. And finally Pump #3 was tested alone at several speeds. No pumps were run in tandem.

6.5.2 Measuring Protocol – Pump Floor

Data were read on the pump floor as follows:

- Flow: the pump flow was read directly from the Panametrics flow meter data display and hand recorded.
- Pressure: the discharge pressure from the pump was read directly from the dial gauge and hand recorded.
- Pump Speed: the pump speed was read from the drive shaft using the hand-held tachometer.
- Time: the time of the reading was taken from a wristwatch that was compared to the control panel clock.

6.5.3 Measuring Protocol – Main Control Room

Data were read in the main control room as follows:

- Flow: the total station flow and individual pump flow were read directly from the control panel.
- Pressure: no discharge pressure reading was available on the main control panel.
- Wet Well Elevation: the wet well elevation was read from the control panel at the time of the pump run.
- Pump Speed: the pump speed was read directly from the control panel at the time of the pump run. The pumps were run at several different speeds to obtain a spread of points on the system head curve.

- Motor Operating Amps: the operating amps of the pump motor were recorded for reference for each pump run.
- Time: the time of the reading was read from the control panel.

6.5.4 Hollywood Pump Station: Collected Data

This section presents and compares the data collected at the Hollywood Pump Station. Data were collected on the pump floor using portable measuring devices, at the control panel, and from the CATAD system.

Table 9 presents the hand recorded data taken on November 9th. Table 10 summarizes the differences between the hand recorded data on the pump floor and the corresponding data recorded in the control room. This gives an indication of the error present between the control panel readings and the data readings from the portable measuring devices.

Table 11 summarizes and compares the pump station data and CATAD data. The table compares pump-on time, wet well elevation, pump flow, and pump speed.

Figures A-27 through A-39 in the Appendix graph the data collected at the pump floor, control panel, and CATAD system. If the data matched exactly, it would plot along a 1:1 slope on the graph. These plots show how the data compare.

Table 9: Hollywood Pump Station Recorded Data

Run #	Date	Time (Main Floor)	Pump #	Wet Well Elev. (ft)	Amps	Control Panel Flow, Pump Total (MGD)	*Control Panel Flow, Pump Total (gpm) (Calculated)*	Speed (rpm)	Time (Pump Floor)	Test Meter Flow (gpm)	Observed Flow Variance (gpm)	Pressure Gage (psi)	*Pressure (ft) (Calc)*	Hand-Held Tachometer (rpm)
01	11/9/99	9:17	3	107.7	81.0	7.30	*5,069*	840	9:18	5,400	100	10.25	*23.6*	806.0
02	11/9/99	9:27	3	108.0	72.0	6.50	*4,514*	790	9:28	4,950	50	10.10	*23.3*	760.0
03	11/9/99	9:39	3	108.4	68.0	4.90	*3,403*	715	9:41	3,970	30	9.40	*21.7*	662.0
04	11/9/99	9:49	3	108.6	62.0	3.50	*2,431*	625	9:49	3,100	50	9.00	*20.8*	600.0
04a	11/9/99								9:49	2,800	50	9.00	*20.8*	600.0
05	11/9/99	9:58	3	109.0	60.0	2.20	*1,528*	565	9:58	2,150	20	8.50	*19.6*	535.0
06	11/9/99	10:15	3	108.5	58.0	1.00	*694*	500	10:15	1,460	100	8.20	*18.9*	478.0
06a	11/9/99								10:15	1,200	100	8.20	*18.9*	478.0
07	11/9/99	12:14	2	108.2	89.0	7.60	*5,278*	800	12:14	5,200	100	6.60	*15.2*	769.0
08	11/9/99	12:20	2	108.4	72.0	6.80	*4,722*	700	12:21	4,300	50	7.00	*16.2*	665.0
09	11/9/99	12:26	2	108.4	64.0	5.10	*3,541*	600	12:26	3,640	100	8.40	*19.4*	513.0
10	11/9/99	12:32	2	108.8	60.0	4.20	*2,917*	540	12:33	3,000	100	8.30	*19.2*	534.0
11	11/9/99	13:41	1	107.6	84.0	8.05	*5,590*	855	13:46	5,800	100	10.50	*24.2*	843.0
12	11/9/99	13:51	1	108.6	69.0	6.30	*4,375*	720	13:55	4,200	100	10.00	*23.1*	729.0
13	11/9/99	13:59	1	107.8	62.5	4.80	*3,333*	650	14:02	3,700	100	9.50	*21.9*	668.0
14	11/9/99	14:05	1	109.0	56.0	2.60	*1,8056*	520	14:10	1,800	50	9.70	*22.4*	517.0

Note: Columns in Italics are calculated and were not recorded in the field

Table 10: Hollywood Pump Station Summary of Errors Between Pump Floor and Control Room Data Readings

Run #	Date	Pump #	Control Panel Flow, Pump Total (MGD)	*Control Panel Flow, Station Total (gpm)*	Test Meter Flow (gpm)	Flow Variance (gpm)	Flow Difference (gpm)	% Difference Meter to Control Panel	% Difference Variance to Control Panel	Control Panel Speed (rpm)	Hand-Held Tachometer (rpm)	Speed Difference (rpm)	% Difference Tachometer to Control Panel
01	11/9/99	3	7.30	*5,069.4*	5,400	100	-331	-6.5%	2.0%	840	806.0	34.0	4.0%
02	11/9/99	3	6.50	*4,513.9*	4,950	50	-436	-9.7%	1.1%	790	760.0	30.0	3.8%
03	11/9/99	3	4.90	*3,402.8*	3,970	30	-567	-16.7%	0.9%	715	662.0	53.0	7.4%
04	11/9/99	3	3.50	*2,430.6*	3,100	50	-669	-27.5%	2.1%	625	600.0	25.0	4.0%
04a	11/9/99			*0.0*	2,800	50	na	na	na		600.0	na	na
05	11/9/99	3	2.20	*1,527.8*	2,150	20	-622	-40.7%	1.3%	565	535.0	30.0	5.3%
06	11/9/99	3	1.00	*694.4*	1,460	100	-766	-110.2%	14.4%	500	478.0	22.0	4.4%
06a	11/9/99			*0.0*	1,200	100	na	na	na		478.0	na	na
07	11/9/99	2	7.60	*5,277.8*	5,200	100	78	1.5%	1.9%	800	769.0	31.0	3.9%
08	11/9/99	2	6.80	*4,722.2*	4,300	50	422	8.9%	1.1%	700	665.0	35.0	5.0%
09	11/9/99	2	5.10	*3,541.7*	3,640	100	-98	-2.8%	2.8%	600	513.0	87.0	14.5%
10	11/9/99	2	4.20	*2,916.7*	3,000	100	-83	-2.9%	3.4%	540	534.0	6.0	1.1%
11	11/9/99	1	8.05	*5,590.3*	5,800	100	-210	-3.8%	1.8%	855	843.0	12.0	1.4%
12	11/9/99	1	6.30	*4,375.0*	4,200	100	175	4.0%	2.3%	720	729.0	-9.0	-1.3%
13	11/9/99	1	4.80	*3,333.3*	3,700	100	-367	-11.0%	3.0%	650	668.0	-18.0	-2.8%
14	11/9/99	1	2.60	*1,805.6*	1,800	50	6	0.3%	2.8%	520	517.0	3.0	0.6%

Note: Columns in italics are calculated and were not recorded in the field

Table 11: Hollywood Pump Station Summary of Errors Between Pump Station Data and CATAD Data

Run #	Date	Time Control Panel	Time Pump Floor	Pump On CATAD	Pump #	Control Panel Wet Well El. (ft)	CATAD Wetwell El.	% Difference Control Panel to CATAD	Control Panel Pump Total (mgd)	CATAD Pump Flow (mgd)	% Diff. Control Panel to CATAD Flow	Portable Flow Meter Pump (mgd)	% Diff. Port. Meter to CATAD Flow	Control Panel (rpm)	Hand-Held Tachometer (rpm)	CATAD rpm	% Diff. Control Panel rpm to CATAD	% Diff Tachometer to CATAD
01	11/9/99	9:17	9:18	9:17	3	107.7	107.60	-0.09%	7.30	8.4	13.10%	7.78	7.43%	840	806.0	841.0	0.12%	4.16%
02	11/9/99	9:27	9:28	9:28	3	108.0	108.11	0.10%	6.50	7.48	13.10%	7.13	4.71%	790	760.0	795.0	0.63%	4.40%
03	11/9/99	9:39	9:41	9:41	3	108.4	108.50	0.09%	4.90	5.89	16.81%	5.72	2.94%	715	662.0	714.5	-0.07%	7.35%
04	11/9/99	9:49	9:49	9:50	3	108.6	108.64	0.04%	3.50	4.04	13.37%	4.46	-10.50%	625	600.0	623.2	-0.29%	3.73%
04a	11/9/99	9:49	9:49	9:50	3	108.6	108.64	0.04%	3.50	4.04	13.37%	4.03	0.20%	625	600.0	623.2	-0.29%	3.73%
05	11/9/99	9:58	9:58	9:58	3	109.0	109.13	0.12%	2.20	3.16	30.38%	3.10	2.03%	565	535.0	571.4	1.11%	6.36%
06	11/9/99	10:15	10:15	10:16	3	108.5	109.42	0.84%	1.00	1.2	16.67%	2.10	-75.20%	500	478.0	500.4	0.08%	4.47%
06a	11/9/99	10:15	10:15	10:16	3	108.5	109.42	0.84%	1.00	1.2	16.67%	1.73	-44.00%	500	478.0	500.4	0.08%	4.47%
07	11/9/99	12:14	12:14	12:14	2	108.2	108.30	0.09%	7.60	8.37	9.20%	7.49	10.54%	800	769.0	776.7	-3.01%	0.99%
08	11/9/99	12:20	12:21	12:21	2	108.4	108.50	0.09%	6.80	8.1	16.05%	6.19	23.56%	700	665.0	707.0	0.99%	5.94%
09	11/9/99	12:26	12:26	12:27	2	108.4	108.46	0.06%	5.10	5.84	12.67%	5.24	10.25%	600	513.0	605.8	0.95%	15.31%
10	11/9/99	12:32	12:33	12:34	2	108.8	108.48	-0.29%	4.20	4.97	15.49%	4.32	13.08%	540	534.0	521.3	-3.60%	-2.44%
11	11/9/99	13:41	13:46	13:44	1	107.6	108.53	0.86%	8.05	7.99	-0.75%	8.35	-4.53%	855	843.0	846.1	-1.05%	0.37%
12	11/9/99	13:51	13:55	13:52	1	108.6	108.77	0.16%	6.30	6.57	4.11%	6.05	7.95%	720	729.0	737.0	2.31%	1.09%
13	11/9/99	13:59	14:02	13:59	1	107.8	107.89	0.08%	4.80	4.81	0.21%	5.33	-10.77%	650	668.0	644.0	-0.93%	-3.72%
14	11/9/99	14:05	14:10	14:06	1	109.0	109.12	0.11%	2.60	2.84	8.45%	2.59	8.73%	520	517.0	545.7	4.70%	5.25%

6.6 Hollywood Pump Station – Data Analysis

The data collected during the pump runs was analyzed and corrected in order to develop pump curves. These pump curves were compared to manufacturer's pump curves and/or pump data provided by the County.

The pump data were corrected by using the pump affinity laws. These laws are used to convert/correct flow and pressure data collected at a given pump speed to a set curve speed. This is done by multiplying the square of the ratio of curve speed to pump speed to correct for head, and multiplying the ratio of curve speed to pump speed to correct for flow.

The total differential head is calculated by adding the discharge head, velocity head, and suction head; and subtracting from this total the inlet head. The suction head for the pump station is calculated by adding the minor losses and friction losses of the inlet piping. This is calculated from each pump run based upon the measured flow.

Table 12 summarizes the data correction calculations and shows the corrected pump data. All pumps have been corrected to a pump speed of 822 rpm. This speed is within the optimal operating range for the pumps.

Figures 9 through 11 are plots of the corrected pump curves. Also shown on each figure is the factory curve generated from data provided by the pump manufacturer and/or the County's modeling database.

Table 12: Hollywood Pump Station – Table of Corrected Pump Data

FIELD DATA						CORRECTED					CORRECTED			FLOW FROM
RUN NO.	PUMP NO.	BUBBLER LEVEL (ft)	TEST METER FLOW (gpm)	DISC. PRESS. (psi)	SPEED RPM	INLET HEAD	SUCTION HEAD	DISCH. HEAD (ft)	VELOCITY HEAD LOSS	TEST TOTAL HEAD	CURVE RPM	HEAD	FLOW	FACTORY CURVE
FIRST RUN, PUMP #3 BETWEEN 9:17 AND 10:15														
1	3	107.7	5,400	10.25	806	4.0	0.9	23.7	2.3	22.9	822	**23.8**	**5507**	5780
02	3	108.0	4,950	10.10	760	4.3	0.7	23.3	1.9	21.8	822	**25.4**	**5354**	5520
03	3	108.4	3,970	9.40	662	4.7	0.5	21.7	1.2	18.8	822	**29.0**	**4930**	4920
04	3	108.6	3,100	9.00	600	4.8	0.3	20.8	0.8	17.0	822	**31.9**	**4247**	4560
04a	3	108.6	2,800	9.00	600	4.8	0.2	20.8	0.6	16.8	822	**31.5**	**3836**	4480
05	3	109.0	2,150	8.50	535	5.3	0.1	19.6	0.4	14.9	822	**35.2**	**3303**	3480
06	3	108.5	1,460	8.20	478	4.8	0.1	18.9	0.2	14.4	822	**42.7**	**2511**	2120
06a	3	108.5	1,200	8.20	478	4.8	0.05	18.9	0.1	14.4	822	**42.4**	**2064**	2160
SECOND RUN, PUMP #2 BETWEEN 12:14 AND 12:32														
07	2	108.2	5,200	6.6	769	4.5	0.8	15.2	2.1	13.7	822	**15.7**	**5558**	6760
08	2	108.4	4,300	7.0	665	4.7	0.6	16.2	1.5	13.5	822	**20.6**	**5315**	6240
09	2	108.4	3,640	8.4	513	4.7	0.4	19.4	1.0	16.2	822	**41.5**	**5833**	2360
10	2	108.8	3,000	8.3	534	5.1	0.3	19.2	0.7	15.1	822	**35.7**	**4618**	3520
THIRD RUN, PUMP #1 BETWEEN 13:41 AND 14:05														
11	1	107.6	5,800	10.5	843	3.6	1.02	24.3	2.6	24.3	822	**23.1**	**5656**	5880
12	1	108.6	4,200	10.0	729	4.6	0.54	23.1	1.4	20.4	822	**26.0**	**4736**	5400
13	1	107.8	3,700	9.5	668	3.8	0.42	21.9	1.1	19.6	822	**29.7**	**4553**	4760
14	1	109.0	1,800	9.7	517	5.0	0.10	22.4	0.3	17.8	822	**44.9**	**2862**	1640

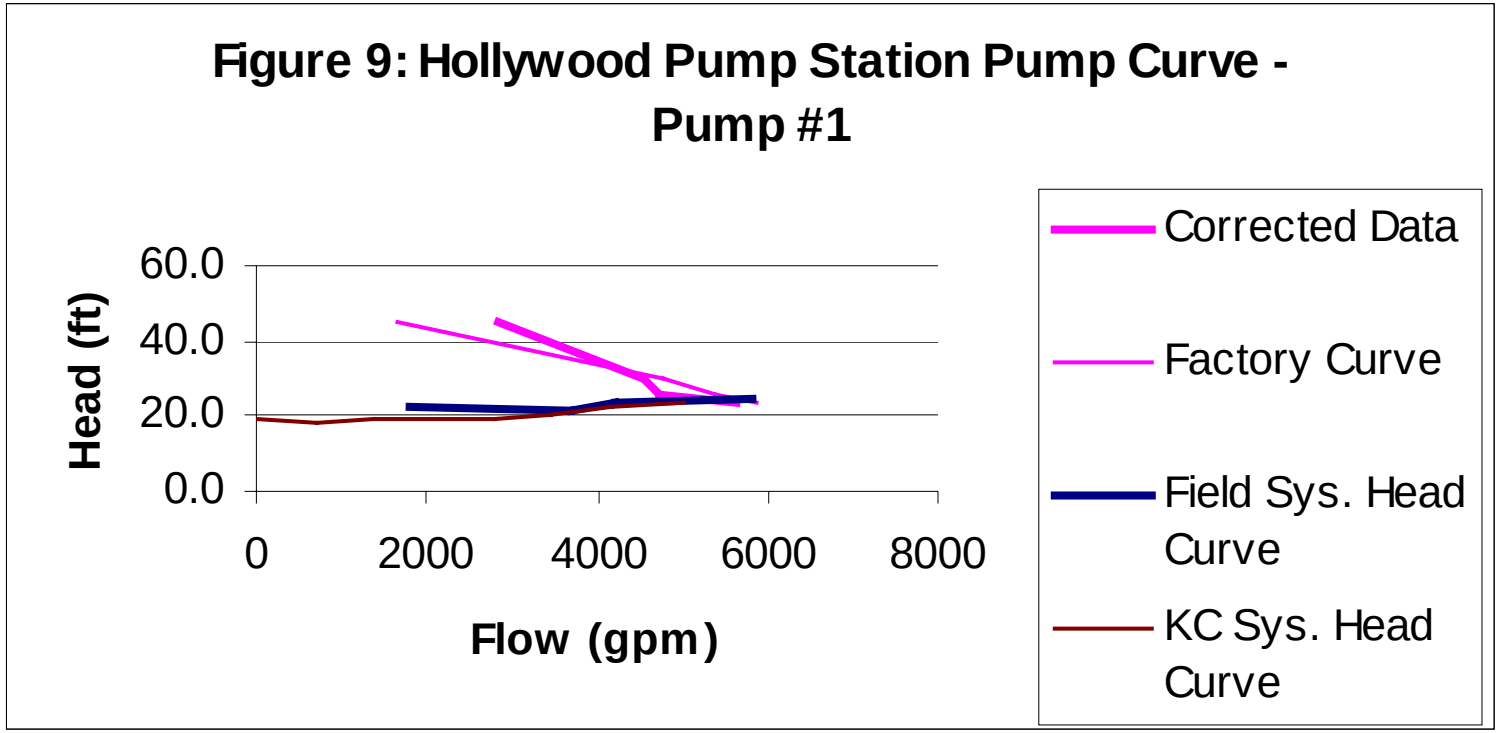


Figure 9: Hollywood Pump Station Pump Curve - Pump #1
Head (ft)
60.0
40.0
20.0
0.0
0
2000
4000
6000
8000
Flow (gpm)
Corrected Data
Factory Curve
Field Sys. Head Curve
KC Sys. Head Curve

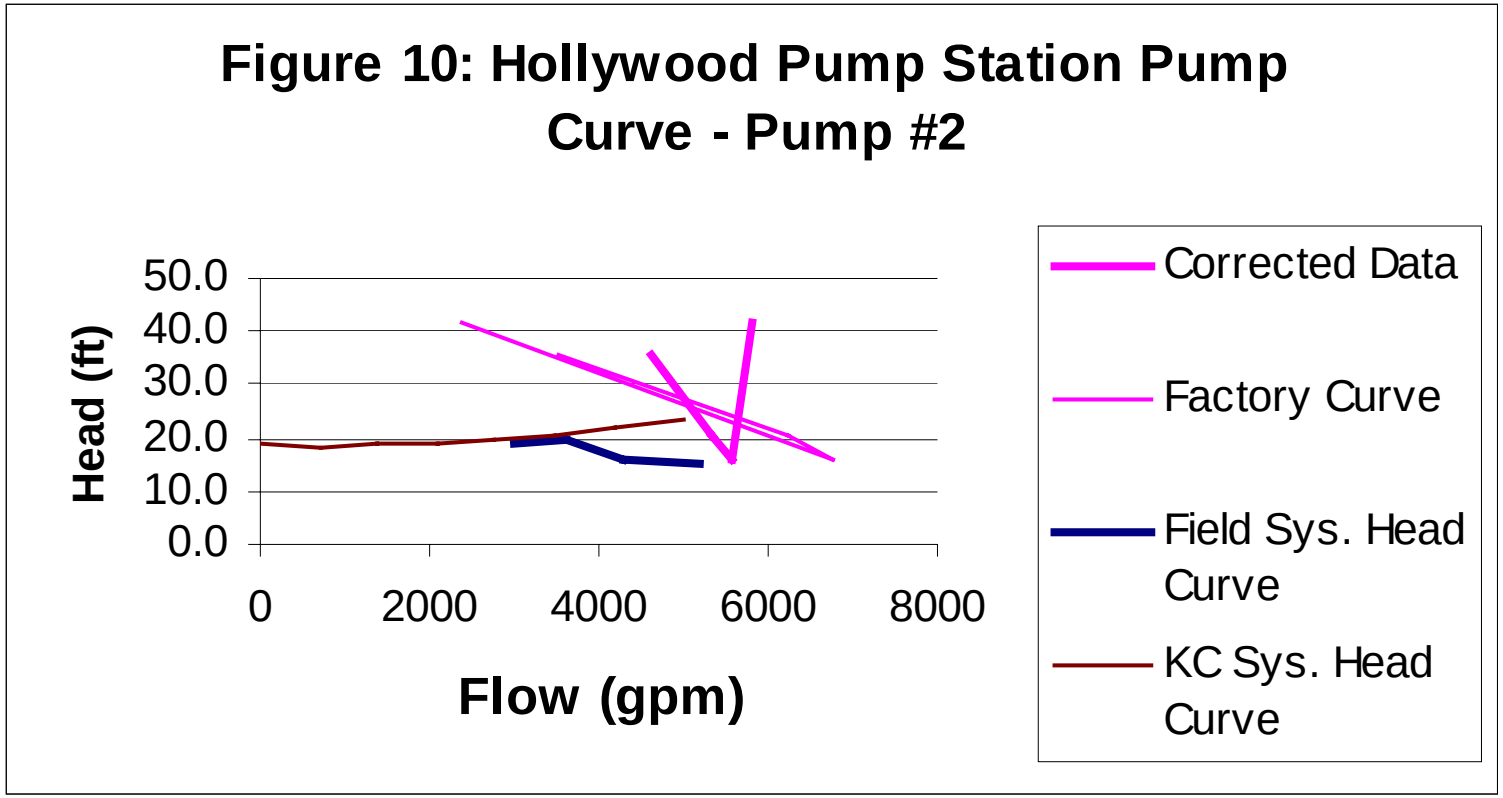
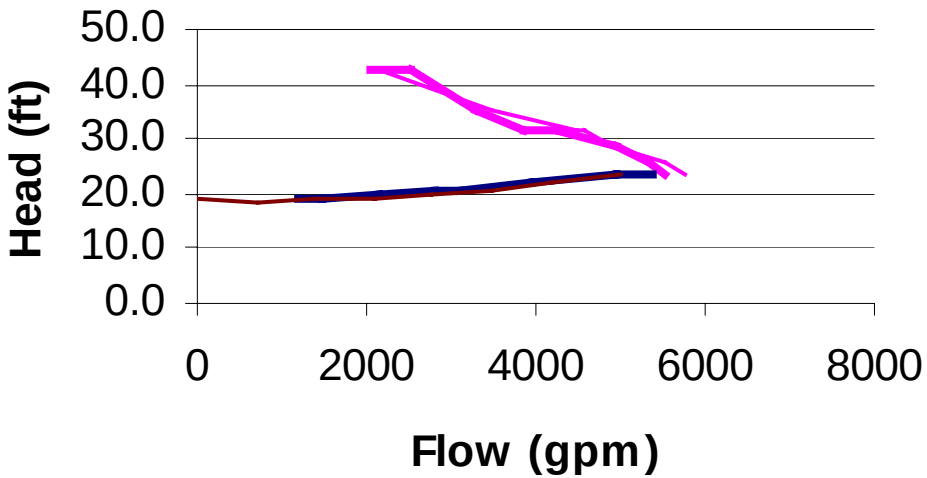


Figure 10: Hollywood Pump Station Pump Curve - Pump #2
Head (ft)
50.0
40.0
30.0
20.0
10.0
0.0
0
2000
4000
6000
8000
Flow (gpm)
Corrected Data
Factory Curve
Field Sys. Head Curve
KC Sys. Head Curve

Figure 11: Hollywood Pump Station Pump Curve - Pump #3



6.7 Hollywood Pump Station – Observations & Recommendations:

Summarized below are the observations and recommendations for the flow, wet well elevation, and speed measurement. According to the scope of work, an error range within 10% is considered acceptable according to the Hydraulics Institute for Field Testing.

6.7.1 Flow Measurement:

Control Panel Flow vs. Portable Meter Flow:

- Pump #1 – There is good correlation between the test data and the control panel data. The average error is approximately 2.6%. Recalibration of the Pump #1 station flow meter is unnecessary.
- Pump #2 – There is good correlation between the test data and the control panel data. The average error is approximately 1.2%. Recalibration of the Pump #2 station flow meter is unnecessary.
- Pump #3 – There is not good correlation between the pump station flow meter and the test data. The average error is approximately 15%. The station flow meter reads consistently below the test flow meter. The station flow meter should be recalibrated.

Control Panel Flow vs. CATAD Flow Readings:

- Pump #1 – The data readings for the control panel flow and CATAD flow show good correlation. The average error between the control panel and CATAD flow data was approximately 3%. There is no need to check or recalibrate the Pump #1 flow meter signal between the station control panel and the CATAD system.
- Pump #2 – There is not good correlation between the Pump #2 station flow meter signal and the CATAD system. The CATAD system records higher flow values than the station control panel reading. The signal should be checked and recalibrated for the Pump #2 flow meter signal to the CATAD system.
- Pump #3 – There is not good correlation between the Pump #3 station flow meter signal and the CATAD system. The CATAD system records higher flow values than the station control panel reading. The signal should be checked and recalibrated for the Pump #3 flow meter signal to the CATAD system.

6.7.2 Speed Measurement

Control Panel Tachometer vs. Hand- Held Tachometer:

- Pump #1 – There is good correlation between the Pump #1 control panel speed reading and the tachometer readings taken on the pump floor. The average error between the readings was less than 1%. There is no need to recalibrate the Pump #1 speed meter on the Control Panel.

- Pump #2 – There is good correlation between the Pump #2 control panel speed readings and the tachometer readings taken on the pump floor. The average error between the control panel readings and the hand-held tachometer readings was approximately 6%. Due to the low percent error it is not necessary to recalibrate the control panel tachometer for Pump #2. There were a few erratic readings that can be seen in the plot of the data. This could be due to the speed control system not stabilizing before the data was recorded.
- Pump #3 – The control panel speed readings and the tachometer readings for Pump #3 show good correlation. The average error between the control panel readings and the hand-held tachometer readings was approximately 5%. Due to the low percent error it is not necessary to recalibrate the control panel tachometer for Pump #3.

Control Panel RPM vs. CATAD RPM:

- Pump #1 – The data between the Pump #1 control panel speed and the CATAD system show good correlation. The average error between the readings is approximately 1%. There is no need to check or calibrate the pump speed signal to the CATAD system for Pump #1.
- Pump #2 – There is good correlation between the Pump #2 control panel speed and the CATAD system reading. The average error between readings is approximately 1%. There is no need to calibrate the pump speed signal to the CATAD system for Pump #2.
- Pump #3 – There is good correlation between the Pump #3 control panel speed and the CATAD system reading. The average error between readings is less than 1%. There is no need to check or calibrate the pump speed signal to the CATAD system for Pump #3.

6.7.3 Wet Well Elevation Measurement

Control Panel Wet Well Elevation vs. CATAD Wet Well Elevation:

- The plot of the control panel wet well elevation and the CATAD wet well readings show good correlation. The plot appears erratic but the percent error between the control panel wet well elevations and the CATAD wet well elevations are less than 1%. The erratic plot is due to scale of the graph. There is no need to check or calibrate the signal between the control panel wet well meter and the CATAD data system.

6.7.4 Pump Curves

Pump #1:

- The corrected flow and head data from the test runs somewhat approximate the factory curve data. The slope of the curve is somewhat steeper than the factory curve.

Pump #2:

- The corrected data made an erratic plot and does not appear to approximate the factory curve data. One data point is suspect since it has the highest head and the highest flow value. Since there were only 3 points taken on this constant speed pump, no data points were thrown out. The field data may have been flawed due to unsteady flow, head, and speed readings during the pump test. This could have been caused by human error, speed fluctuations in the pump, and wet well elevations changing due to low influent flow rates during the pump tests.

Pump #3:

- The corrected flow data from the test runs and the factory curve data showed a high degree of correlation. The corrected data plotted closely with the factory data curve.

SECTION 7 YORK PUMP STATION

7.1 Background

The York Pump Station is located west of the Sammamish River, at the intersection of Willows Rd NE and NE 124th Street. The station receives wastewater flow from the NE Lake Sammamish Interceptor. Wastewater is pumped through a 30-inch and 48-inch diameter force main to the north end of the East Side Interceptor. The wet well can be drained back towards the Hollywood Pump Station if necessary. This pump station also receives flow from the North Creek Pump Station during the winter.

7.2 Pump Station Design Information

Key design information for the York Pump Station is summarized in the table below.

York Pump Station Elevation Information (Metro Datum)

Pump Room Floor	100.67 ft
Wet Well Grating	112.00 ft
Motor Room Floor	118.25 ft
Overflow Elevation	124.20 ft
Control Room Floor	134.50 ft

York Pump Station Pump and Motor Information

Pumps #1, #2, and #3:	
Pump:	
Model:	Gould Pumps Inc., model NCD 12X12-25
Capacity:	13.68 mgd, 200 feet TDH, 1,180 rpm
Motor:	
Model:	US Motors , model G47923, frame: 5809-P, 600 hp, 460V, 3-phase

Variable Frequency Drive	
Model:	Robicon Corporation Series ID8001

Pumps #4, #5 & #6:	
Pump:	
Model:	Fairbanks Morse, 12-C2416
Capacity:	10,000gpm, 180 feet TDH, 1185 rpm
Motor:	
Model:	600 hp, 460 V, 3-phase

7.3 Key Points and Issues

There were several key points and issues discovered during the testing and data analysis of the York Pump Station. They are summarized below:

- Pumps #1, #2, & #3 were initially installed in the pump station. They are variable speed pumps. A single manufacturer's pump curve was provided for all three pumps.
- Pumps #4, #5, & #6 were installed recently. They are constant speed pumps. A single manufacturer's pump curve was provided for all three pumps. Pump #6 was not operational since it had problems with some of its bearings. The installation contractor was still doing work on the installation of Pump #4, #5, & #6.
- The pumps discharge into a force main header. This force main header transitions to 20-inch and 40-inch parallel pipes. These pipes transition to the 30-inch and 48-inch force mains which go to the Eastside Interceptor. Flow is directed to the 20-inch or 40-inch force main header by an air actuated plug valve.
- The current control strategy for the force mains are as follows: 1) the 20-inch pipe (30-inch force main) is used for flow up to 15,000 gpm. 2) the flow is then switched to the 40-inch pipe (48-inch force main) for flows between 15,000 and 30,000 gpm. 3) both force mains are used for flows above 30,000 gpm.

- There were no locations along the pump discharge piping from each pump to mount the flow transducers and get accurate readings. The transducers were mounted on the 20-inch force main for tests performed on Pumps #1 & #3. The transducers were mounted on the 40-inch force main for tests performed on Pumps #4 & #5.
- Tests were attempted on Pump #2 but the pump was unable to startup and get to operating speed without disengaging and stopping. It was determined that something was probably wrong with the VFD and/or control system. No tests were conducted or data collected for this pump.
- The tests performed for Pumps #1 & #3 were conducted with each pump being operated alone at different speeds. The tests performed for Pumps #4 & #5 were conducted in tandem with other pumps since they are constant speed pumps. This was done in order to get flow and pressure data within the force main to be used for the County's computer model.
- Although the data taken using Pump #4 and #5 were intended to get force main information, we attempted to develop a pump curve for Pump #5 from the flow and pressure readings from the Pump #4 & #5 tandem test runs. However, there was a problem when conducting the data analysis and trying to develop a pump curve. This problem was caused by the difficulty in determining what part of the flow measured in the force main is from the pump being studied and what part is from the additional pump(s) being operated in tandem. The flow from the pump(s) being operated in tandem was estimated from the County's computer model pump curve for that pump and subtracted from the measured flow. This approximation causes the pump curve for Pumps #5 to appear erratic when using this data.

7.4 Measuring Equipment Setup at York Pump Station

On the pump floor, a pressure gauge was installed on the pump discharge. The tap was located on the edge of the discharge flange. A strap-on flow meter was positioned on the force main header being used 20-inch or 40-inch, immediately upstream of the station's magnetic flow meters. The meter installation required paint to be chipped from the force main header and a thickness measurement of the pipe wall where the flow transducers were mounted was taken using an ultrasonic thickness gage. Figure DIA – 4 in the Appendix is a schematic diagram of the piping and approximate equipment locations.

Pressure gauge readings were taken from the installed pressure gauges on the pump discharges and from the force main pressure gauges located on the pump room floor. Pressure gauge readings were read directly and hand recorded. The elevation from the centerline of the volute to the pump floor was measured to correct the pressure gauge reading. The discharge pressure readings taken at the pump discharge were used to calculate total dynamic head.

The wet well level was recorded for each pump run from the control panel. The wet well level bubbler was checked by measuring the distance to the water surface from the grate. When the elevation was calculated using the grate elevation from the record drawings, it checked exactly with the control panel elevation.

No data logger was used.

No calibration stickers were found.

7.5 Measuring Protocol at York Pump Station

7.5.1 Testing Sequence

The pumps were tested in a single day (November 15, 1999). Pump #1 was tested first at several speeds. This was done to get several points along the pump curve. Pump #3 was then tested at several speeds. The portable flow meter was then switched from the 20-inch force main header to the 40-inch force main header. Then tests were conducted for Pumps #4 and #5.

7.5.2 Measuring Protocol – Pump Floor

Data were read on the pump floor as follows:

- Flow: the pump flow was read directly from the Panametrics flow meter data display and hand recorded.
- Pressure: the discharge pressure from the pump was read directly from the dial gauge at the pump discharge and hand recorded.
- Pump Speed: the pump speed was read from the drive shaft using the hand-held tachometer.
- Time: the time of the reading was taken from a wristwatch which was compared to the control panel clock.

7.5.3 Measuring Protocol – Main Control Room

Data were read in the main control room as follows:

- Flow: the total station flow was read directly from the control panel for the force main being used (i.e.) the 30-inch or 48-inch diameter force main.
- Pressure: The header pressure was read and recorded from the control panel.
- Wet Well Elevation: the wet well elevation was read from the control panel at the time of the pump run.
- Pump Speed: the pump speed was read directly from the control panel at the time of the pump run.
- Motor Operating Amps: the operating amps of the pump motor were recorded for reference for each pump run.

- Time: the time of the pump test and data recording was read from the control panel.

7.5.4 York Pump Station: Collected Data

This section presents and compares the data collected at the York Pump Station. Data were collected on the pump floor using portable measuring devices, at the control panel, and from the CATAD system.

Table 13 presents the hand-recorded data taken on November 9th. Table 14 summarizes the differences between the hand-recorded data on the pump floor and the corresponding data recorded in the control room. This gives an indication of the error present between the control panel readings and the data readings from the portable measuring devices.

Table 15 summarizes and compares the pump station data and CATAD data. The table compares pump-on time, wet well elevation, pump flow, and pump speed.

Figures A-40 through A-50 in the Appendix graph the data collected at the pump floor, control panel, and CATAD system. If the data matched exactly, it would plot along a 1:1 slope on the graph. These plots show how the data compare.

Table 13: York Pump Station Recorded Data

Run #	Date	Time (Main Floor)	Pump #	Wet Well Elev. (ft)	Amps (%)	Control Panel Flow Station Total (gpm)	*Control Panel Flow Station Total (MGD (Calc)*	Header Press. (psi)	30" FM Press. (psi)	48" FM Press. (psi)	Speed (rpm)	Time (Pump Floor)	Test Meter Flow (gpm)	Pump Press. (psi)	*Pump Pressure (ft) (Calc)*	Hand-Held Tach (rpm)	Station Flow Meter (%, 0-20K)	30"Force Main Portable (psi)	*30"Force Main Portable (ft)*	30"Force Main Wall (psi)	*30"Force Main Wall (ft)*
01	11/15/99	9:58	1	107.1	69.0	6800.00	*9.8*	73.0	NR	No Flow	1106	9:57	5,860	71.00	*163.9*	1105.0	36.0	NR		NR	
02	11/15/99	10:06	1	107.3	64.0	5100.00	*7.3*	72.0	NR	No Flow	1075	10:06	5,270	70.00	*161.6*	1075.0	32.0	NR		NR	
03	11/15/99	10:12	1	107.5	60.0	4500.00	*6.5*	72.0	NR	No Flow	1050	10:15	4,800	69.00	*159.3*	1049.0	28.5	NR		NR	
04	11/15/99	10:15	1	107.6	56.0	4200.00	*6.0*	72.0	NR	No Flow	1026	10:18	4,250	68.50	*158.1*	1025.0	27.5	NR		NR	
05	11/15/99	10:18	1	107.7	52.0	4100.00	*5.9*	71.0	NR	No Flow	1001	10:21	3,650	68.00	*156.9*	1001.0	25.5	NR		NR	
06	11/15/99	10:21	1	107.9	50.0	3200.00	*4.6*	71.0	NR	No Flow	989	10:24	3,340	67.50	*155.8*	988.0	19.5	NR		NR	
07	11/15/99	11:30	3	108.4	80.0	8200.00	*11.8*	75.0	NR	No Flow	1124	11:33	7,050	73.00	*168.5*	1123.0	35.5	NR		NR	
08	11/15/99	11:33	3	108.4	76.0	7600.00	*10.9*	74.0	NR	No Flow	1099	11:35	6,850	72.50	*167.3*	1098.0	34.5	NR		NR	
09	11/15/99	11:36	3	108.5	72.0	7000.00	*10.1*	73.0	NR	No Flow	1072	11:39	6,300	72.00	*166.2*	1071.0	32.5	NR		NR	
10	11/15/99	11:39	3	108.5	67.0	6000.00	*8.6*	73.0	NR	No Flow	1045	11:42	5,350	71.00	*163.9*	1045.0	29.8	NR		NR	
11	11/15/99	11:41	3	108.6	65.0	5100.00	*7.3*	72.0	NR	No Flow	1025	11:44	4,700	71.00	*163.9*	1026.0	28.0	NR		NR	
12	11/15/99	11:44	3	108.6	62.0	5000.00	*7.2*	72.0	NR	No Flow	1007	11:47	4,250	70.00	*161.6*	1007.0	26.8	NR		NR	
13	11/15/99	12:33	4	108.7	575a	10200.0	*14.7*	76.0	73.0	No Flow	1190	12:26	8,800	75.00	*173.1*	1189.0	48.0	72.5	*167.3*	72.5	*167.3*
14	11/15/99	12:38	5	108.7	594a	10100.0	*14.5*	77.0	73.0	No Flow	1190	12:41	8,600	73.00	*168.5*	1190.0	45.0	71.0	*163.9*	72.5	*167.3*
15	11/15/99	13:04	5	108.4	585a	10400.0	*15.0*	79.0	75.0	No Flow	1190	13:06	10,500	NR	*NR*	1190.0			*0*		*0*
15a	11/15/99	13:04	1	-	45.0	-	-	-	-	No Flow	985	13:06		77.00	*177.7*	984.0	51.5	72.5	*167.3*	74.0	*170.8*
16	11/15/99	13:10	5	108.3	582a	11900.0	*17.1*	80.0	76.0	No Flow	1190	13:13	11,500	NR	*NR*	1189.0			*0*		*0*
16a	11/15/99	13:10	1	-	51.0	-	-	-	-	No Flow	1021	13:13		78.00	*180.0*	1021.0	56.0	74.0	*170.8*	75.0	*173.1*
17	11/15/99	13:17	5	108.1	568a	13200.0	*19.0*	82.0	78.0	No Flow	1190	13:20	12,700	NR	*NR*	1190.0			*0*		*0*
17a	11/15/99	13:17	1	-	61.0	-	-		-	No Flow	1073	13:20		81.00	*186.9*	1073.0	62.5	75.0	*173.1*	77.0	*177.7*
18	11/15/99	13:24	5	107.9	566a	13200.0	*19.0*	83.0	78.0	No Flow	1190	13:27	13,200		*0*	1190.0			*0*		*0*
18a	11/15/99	13:24	1		67.0		*0.0*				1109	13:27		82.00	*189.3*	1107.5	63.0	76.0	*175.4*	77.5	*178.9*
19	11/15/99	15:03	5	106.4	599a	25800.0	*37.2*	75.0	No	No	1190	15:06	25,200	73.00	*168.5*	1190.0	26000.0	No Flow		No Flow	
19a	11/15/99	15:03	4		575a		*0.0*				1189				*0*	1189.0		No Flow		No Flow	
19b	11/15/99	15:03	1		72.0		*0.0*				1106				*0*	1104.0		No Flow		No Flow	
20	11/15/99	15:23	5	106.0	599a	19900.0	*28.7*	73.0	No	No	1190	15:25	18,500	86.00	*198.5*	1189.0	20000.0	No Flow		No Flow	
20a	11/15/99	15:23	4		578a		*0.0*				1189				*0*	1189.0		No Flow		No Flow	

Note: Columns in italics are calculated and were not recorded in the field

NR = No Reading

Table 14: York Pump Station Summary of Errors Between Pump Floor and Control Room Data Readings

Run #	Date	Pump #	Control Panel Flow Pump Total (gpm)	Test Meter Flow (gpm)	Flow Difference (gpm)	% Difference Meter to Control Panel	Control Panel Speed (rpm)	Hand-Held Tachometer (rpm)	Speed Difference (rpm)	% Difference Tachometer to Control Panel	Header Pressure (psi)	30"Force Main Portable (psi)	Diff.	% Diff Port. to Header Press.
01	11/15/99	1	6,800	5,860	940	13.8%	1106	1105.0	1.0	0.1%	73.0	no reading	na	
02	11/15/99	1	5,100	5,270	-170	-3.3%	1075	1075.0	0.0	0.0%	72.0	no reading	na	
03	11/15/99	1	4,500	4,800	-300	-6.7%	1050	1049.0	1.0	0.1%	72.0	no reading	na	
04	11/15/99	1	4,200	4,250	-50	-1.2%	1026	1025.0	1.0	0.1%	72.0	no reading	na	
05	11/15/99	1	4,100	3,650	450	11.0%	1001	1001.0	0.0	0.0%	71.0	no reading	na	
06	11/15/99	1	3,200	3,340	-140	-4.4%	989	988.0	1.0	0.1%	71.0	no reading	na	
07	11/15/99	3	8,200	7,050	1,150	14.0%	1124	1123.0	1.0	0.1%	75.0	no reading	na	
08	11/15/99	3	7,600	6,850	750	9.9%	1099	1098.0	1.0	0.1%	74.0	no reading	na	
09	11/15/99	3	7,000	6,300	700	10.0%	1072	1071.0	1.0	0.1%	73.0	no reading	na	
10	11/15/99	3	6,000	5,350	650	10.8%	1045	1045.0	0.0	0.0%	73.0	no reading	na	
11	11/15/99	3	5,100	4,700	400	7.8%	1025	1026.0	-1.0	-0.1%	72.0	no reading	na	
12	11/15/99	3	5,000	4,250	750	15.0%	1007	1007.0	0.0	0.0%	72.0	no reading	na	
13	11/15/99	4	10,200	8,800	1,400	13.7%	1190	1189.0	1.0	0.1%	76.0	72.5	3.5	4.6%
14	11/15/99	5	10,100	8,600	1,500	14.9%	1190	1190.0	0.0	0.0%	77.0	71.0	6.0	7.8%
15	11/15/99	5	10,400	10,500	-100	-1.0%	1190	1190.0	0.0	0.0%	79.0		79.0	
15a	11/15/99	1	-		-		985	984.0	1.0	0.1%	-	72.5	na	
16	11/15/99	5	11,900	11,500	400	3.4%	1190	1189.0	1.0	0.1%	80.0		80.0	
16a	11/15/99	1	-		-		1021	1021.0	0.0	0.0%	-	74.0	na	
17	11/15/99	5	13,200	12,700	500	3.8%	1190	1190.0	0.0	0.0%	82.0		82.0	
17a	11/15/99	1	-		-		1073	1073.0	0.0	0.0%		75.0	-75.0	
18	11/15/99	5	13,200	13,200	0	0	1190	1190.0	0.0	0.0%	83.0		83.0	
18a	11/15/99	1			0		1109	1107.5	1.5	0.1%		76.0	-76.0	
19	11/15/99	5	25,800	25,200	600	2.3%	1190	1190.0	0.0	0.0%	75.0	No Flow	na	
19a	11/15/99	4			0		1189	1189.0	0.0	0.0%		No Flow	na	
19b	11/15/99	1			0		1106	1104.0	2.0	0.2%		No Flow	na	
20	11/15/99	5	19,900	18,500	1,400	7.0%	1190	1189.0	1.0	0.1%	73.0	No Flow	na	
20a	11/15/99	4			0		1189	1189.0	0.0	0.0%		No Flow	na	

Note: Columns in italics are calculated and were not recorded in the field

Table 15: York Pump Station Summary of Errors Between Pump Station Data and CATAD Data

Run #	Date	Time Control Panel	Time Pump Floor	Pump On CATAD	Pump #	Control Panel Wet Well El.	CATAD Wet Well El.	% Difference to Control Panel to CATAD	Control Panel Station Total (mgd)	CATAD Pump Flow (mgd)	% Difference Control Panel to CATAD	Portable Flow Meter Pump (mgd)	% Difference Port. Meter to CATAD	Control Panel (rpm)	Hand-Held Tachometer (rpm)	CATAD (rpm)	% Difference Control Panel rpm to CATAD	% Difference Tachometer to CATAD
01	11/15/99	9:58	9:57	9:59	1	107.1	107.15	0.05%	9.79	9.71	-0.84%	8.44	13.10%	1,106	1105.0	1100.4	-0.51%	-0.42%
02	11/15/99	10:06	10:06	10:08	1	107.3	107.37	0.07%	7.34	7.24	-1.44%	7.59	-4.82%	1,075	1075.0	1122.3	4.22%	4.22%
03	11/15/99	10:12	10:15	10:16	1	107.5	107.64	0.13%	6.48	6.09	-6.40%	6.91	-13.50%	1,050	1049.0	1020.1	-2.93%	-2.84%
04	11/15/99	10:15	10:18	10:20	1	107.6	107.78	0.17%	6.05	5.53	-9.37%	6.12	-10.67%	1,026	1025.0	995.2	-3.10%	-3.00%
05	11/15/99	10:18	10:21	10:25	1	107.7	107.94	0.22%	5.90	5.66	-4.31%	5.26	7.14%	1,001	1001.0	1052.3	4.88%	4.88%
06	11/15/99	10:21	10:24	10:28	1	107.9	107.84	-0.06%	4.61	14.41	68.02%	4.81	66.62%	989	988.0	1103.3	10.36%	10.45%
07	11/15/99	11:30	11:33	11:33	3	108.4	108.46	0.06%	11.81	11.39	-3.67%	10.15	10.87%	1,124	1123.0	1119.4	-0.41%	-0.32%
08	11/15/99	11:33	11:35	11:35	3	108.4	108.46	0.06%	10.94	11.25	2.72%	9.86	12.32%	1,099	1098.0	1094.5	-0.41%	-0.32%
09	11/15/99	11:36	11:39	11:39	3	108.5	108.55	0.05%	10.08	8.82	-14.29%	9.07	-2.86%	1,072	1071.0	1042.6	-2.82%	-2.72%
10	11/15/99	11:39	11:42	11:42	3	108.5	108.60	0.09%	8.64	7.89	-9.51%	7.70	2.36%	1,045	1045.0	1021.8	-2.27%	-2.27%
11	11/15/99	11:41	11:44	11:44	3	108.6	108.63	0.03%	7.34	7.31	-0.47%	6.77	7.41%	1,025	1026.0	1023.0	-0.20%	-0.29%
12	11/15/99	11:44	11:47	11:47	3	108.6	108.66	0.06%	7.20	7.07	-1.84%	6.12	13.44%	1,007	1007.0	1002.8	-0.42%	-0.42%
13	11/15/99	12:33	12:26	12:26	4	108.7	108.89	0.17%	14.69	14.97	1.88%	12.67	15.35%	1,190	1189.0	n/a	n/a	n/a
14	11/15/99	12:38	12:41	12:40	5	108.7	108.75	0.05%	14.54	14.42	-0.86%	12.38	14.12%	1,190	1190.0	n/a	n/a	n/a
15	11/15/99	13:04	13:06	13:06	5	108.4	108.43	0.03%	14.98	14.57	-2.79%	15.12	-3.77%	1,190	1190.0	n/a	n/a	n/a
15a	11/15/99	13:04	13:06	13:06	1	108.4	108.43	0.03%	14.98	14.57	-2.79%	-	n/a	985	984.0	977.9	-0.73%	-0.63%
16	11/15/99	13:10	13:13	13:13	5	108.3	108.27	-0.03%	17.14	17.05	-0.50%	16.56	2.87%	1,190	1189.0	n/a	n/a	n/a
16a	11/15/99	13:10	13:13	14:06	1	108.3	108.27	-0.03%	17.14	17.05	-0.50%	16.56	2.87%	1,021	1021.0	1016.0	-0.50%	-0.50%
17	11/15/99	13:17	13:20	13:20	5	108.1	108.05	-0.05%	19.01	19	-0.04%	18.29	3.75%	1,190	1190.0	n/a	n/a	n/a
17a	11/15/99	13:17	13:20	13:20	1	108.1	108.32	0.20%	19.01	16.37	-16.11%	18.29	-11.72%	1,073	1073.0	1067.0	-0.57%	-0.57%
18	11/15/99	13:24	13:27	13:27	5	107.9	107.80	-0.09%	19.01	18.61	-2.14%	19.01	-2.14%	1,190	1190.0	n/a	n/a	n/a
18a	11/15/99	13:24	13:27	13:27	1	107.9	108.27	0.34%	19.01	18.61	-2.14%	19.01	-2.14%	1,109	1107.5	1101.8	-0.65%	-0.51%
19	11/15/99	15:03	15:06	15:06	5	106.4	105.35	-1.00%	37.15	36.62	-1.45%	36.29	0.91%	1,190	1190.0	n/a	n/a	n/a
19a	11/15/99	15:03	15:06	15:06	4	106.4	105.35	-1.00%	37.15	36.62	-1.45%	36.29	0.91%	1,189	1189.0	n/a	n/a	n/a
19b	11/15/99	15:03	15:06	15:06	1	106.4	105.35	-1.00%	37.15	36.62	-1.45%	36.29	0.91%	1,106	1104.0	1096.3	-0.89%	-0.71%
20	11/15/99	15:23	15:25	22:06	5	106.0	105.40	-0.57%	28.66	28.18	-1.69%	26.64	5.46%	1,190	1189.0	n/a	n/a	n/a
20a	11/15/99	15:23	15:25	22:06	4	106.0	105.40	-0.57%	28.66	28.18	-1.69%	26.64	5.46%	1,189	1189.0	n/a	n/a	n/a

7.6 York Pump Station – Data Analysis

The data collected during the pump runs was analyzed and corrected in order to develop pump curves. These pump curves were compared to manufacturer's pump curves and/or pump data provided by the County.

The pump data were corrected by using the pump affinity laws. These laws are used to convert/correct flow and pressure data collected at a given pump speed to a set curve speed. This is done by multiplying the square of the ratio of curve speed to pump speed to correct for head, and multiplying the ratio of curve speed to pump speed to correct for flow.

The total differential head is calculated by adding the discharge head, velocity head, and suction head; and subtracting from this total the inlet head. The suction head for the pump station is calculated by adding the minor losses and friction losses of the inlet piping. These are calculated for each pump run based upon the measured flow.

Table 16 summarizes the data correction calculations and shows the corrected pump data. All pumps have been corrected to a pump speed of 1180 rpm. This speed is within the optimal operating range for the pumps.

Figures 12 through 14 are plots of the corrected pump curves. Also shown on each figure is the factory curve generated from data provided by the pump manufacturer and/or the County's modeling database.

Table 16: York Pump Station – Table of Corrected Pump Data

FIELD DATA						CORRECTED DATA					CORRECTED			FLOW FROM
RUN NO.	PUMP NO.	BUBBLER LEVEL (ft)	TEST METER FLOW (gpm)	DISC. PRESS. (psi)	SPEED RPM	INLET HEAD	SUCTION HEAD	DISCH. HEAD (ft)	VELOCITY HEAD LOSS	TEST TOTAL HEAD	CURVE RPM	HEAD	FLOW	FACTORY CURVE
FIRST RUN, PUMP #1 BETWEEN 9:58 AND 10:21														
01	1	107.1	5,860	71.00	1105	5.4	1.2	164.0	5.1	164.8	1180	**188.0**	**6258**	9400
02	1	107.3	5,270	70.00	1075	5.6	0.9	161.7	4.1	161.1	1180	**194.1**	**5785**	8700
03	1	107.5	4,800	69.00	1049	5.8	0.8	159.4	3.4	157.8	1180	**199.6**	**5399**	8250
04	1	107.6	4,250	68.50	1025	5.9	0.6	158.2	2.7	155.6	1180	**206.2**	**4893**	7600
05	1	107.7	3,650	68.00	1001	6.0	0.5	157.1	2.0	153.5	1180	**213.3**	**4303**	6950
06	1	107.9	3,340	67.50	988	6.2	0.4	155.9	1.7	151.7	1180	**216.4**	**3989**	6625
SECOND RUN, PUMP #3 BETWEEN 11:30 AND 11:44														
07	3	108.4	7,050	73.00	1123	6.7	1.7	168.6	7.4	170.9	1180	**188.7**	**7408**	9390
08	3	108.4	6,850	72.50	1098	6.7	1.56	167.5	7.0	169.3	1180	**195.5**	**7362**	8510
09	3	108.5	6,300	72.00	1071	6.8	1.3	166.3	5.9	166.7	1180	**202.4**	**6941**	8000
10	3	108.5	5,350	71.00	1045	6.8	1.0	164.0	4.2	162.4	1180	**207.1**	**6041**	7500
11	3	108.6	4,700	71.00	1026	6.9	0.9	164.0	3.3	161.2	1180	**213.3**	**5405**	7050
12	3	108.6	4,250	70.00	1007	6.9	0.8	161.7	2.7	158.3	1180	**217.4**	**4980**	6450
THIRD RUN, PUMPS #4 & #5 BETWEEN 12:33 AND 15:23														
13	4	108.7	8,800	75.00	1189	6.8	2.54	173.3	11.5	180.5	1185	**179.3**	**8770**	
14	5	108.7	8,600	73.00	1190	6.8	2.43	168.6	11.0	175.2	1185	**173.8**	**8564**	10700
15	5	108.4	*7,160*	77.00	1190	6.5	1.70	177.9	7.6	180.7	1185	**179.2**	**7130**	10400
15a	1	-	-	-	984	-	-	-	-	-	1185	**-**	**-**	
16	5	108.3	*7,250*	78.00	1189	6.4	1.74	180.2	7.8	183.3	1185	**182.1**	**7226**	9900
16a	1	108.3	No Reading	No Reading	1021	6.4	n/a	n/a	n/a	n/a	1185	**n/a**	**n/a**	
17	5	108.1	*7,430*	81.00	1190	6.2	1.83	187.1	8.2	190.9	1185	**189.3**	**7399**	9400
17a	1	108.1	No Reading	No Reading	1073	6.4	n/a	n/a	n/a	n/a	1185	**n/a**	**n/a**	
18	5	107.9	*7,340*	82.00	1190	6.0	1.79	189.4	8.0	193.2	1185	**191.6**	**7309**	9200
18a	1	107.9	No Reading	No Reading	1108	6.2	n/a	n/a	n/a	n/a	1185	**n/a**	**n/a**	
19	5	106.4	*10,540*	73.00	1190	4.7	3.60	168.6	16.5	184.0	1185	**182.4**	**10496**	9900
19a	4	106.4	No Reading	No Reading	1189	4.5	n/a	n/a	n/a	n/a	1185	**n/a**	**n/a**	
19b	1	106.4	No Reading	No Reading	1104	4.7	n/a	n/a	n/a	n/a	1185	**n/a**	**n/a**	
20	5	106.0	*9,700*	86.00	1189	4.1	3.07	198.7	14.0	211.6	1185	**210.2**	**9667**	7700
20a	4	106.0	No Reading	No Reading	1189	4.1	n/a	n/a	n/a	n/a	1185	**n/a**	**n/a**	

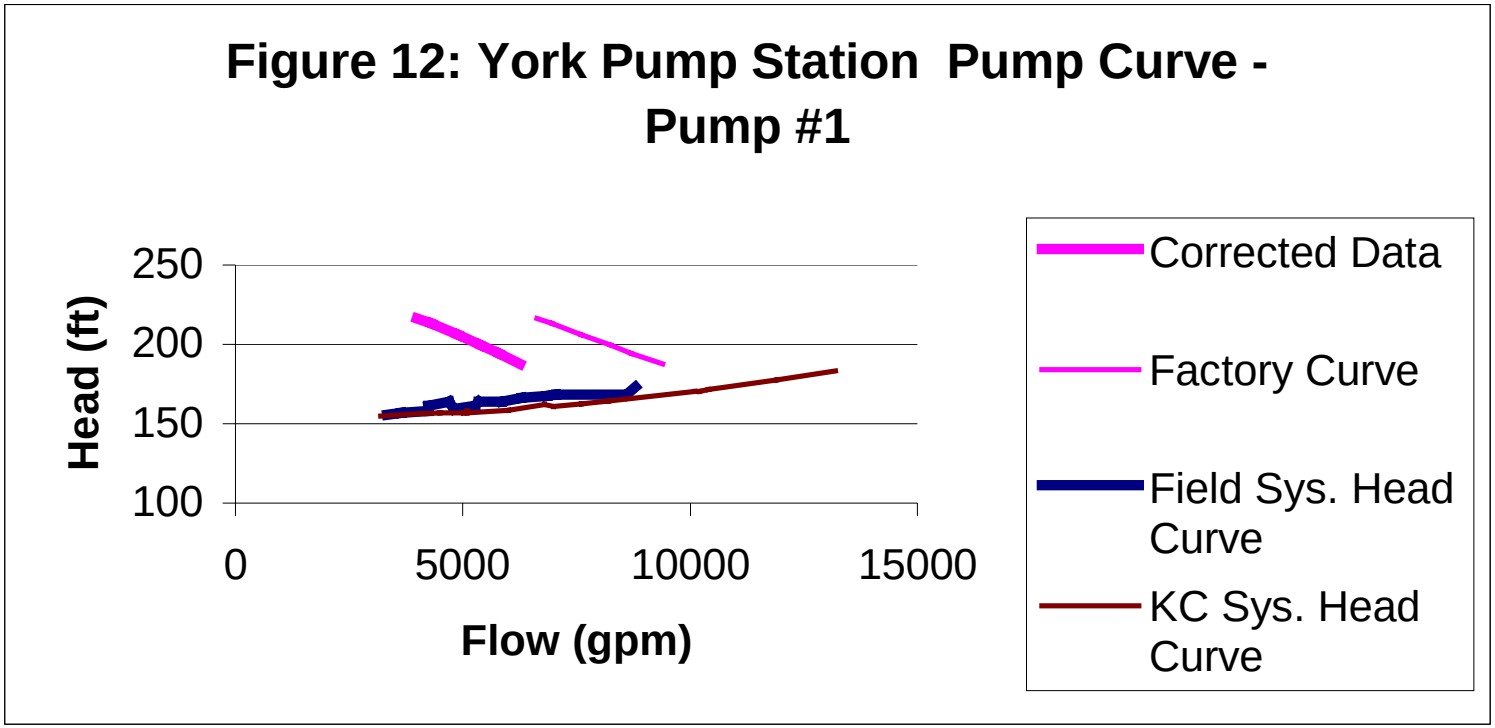


Figure 12: York Pump Station Pump Curve - Pump #1
Head (ft)
250
200
150
100
0
5000
10000
15000
Flow (gpm)
Corrected Data
Factory Curve
Field Sys. Head Curve
KC Sys. Head Curve

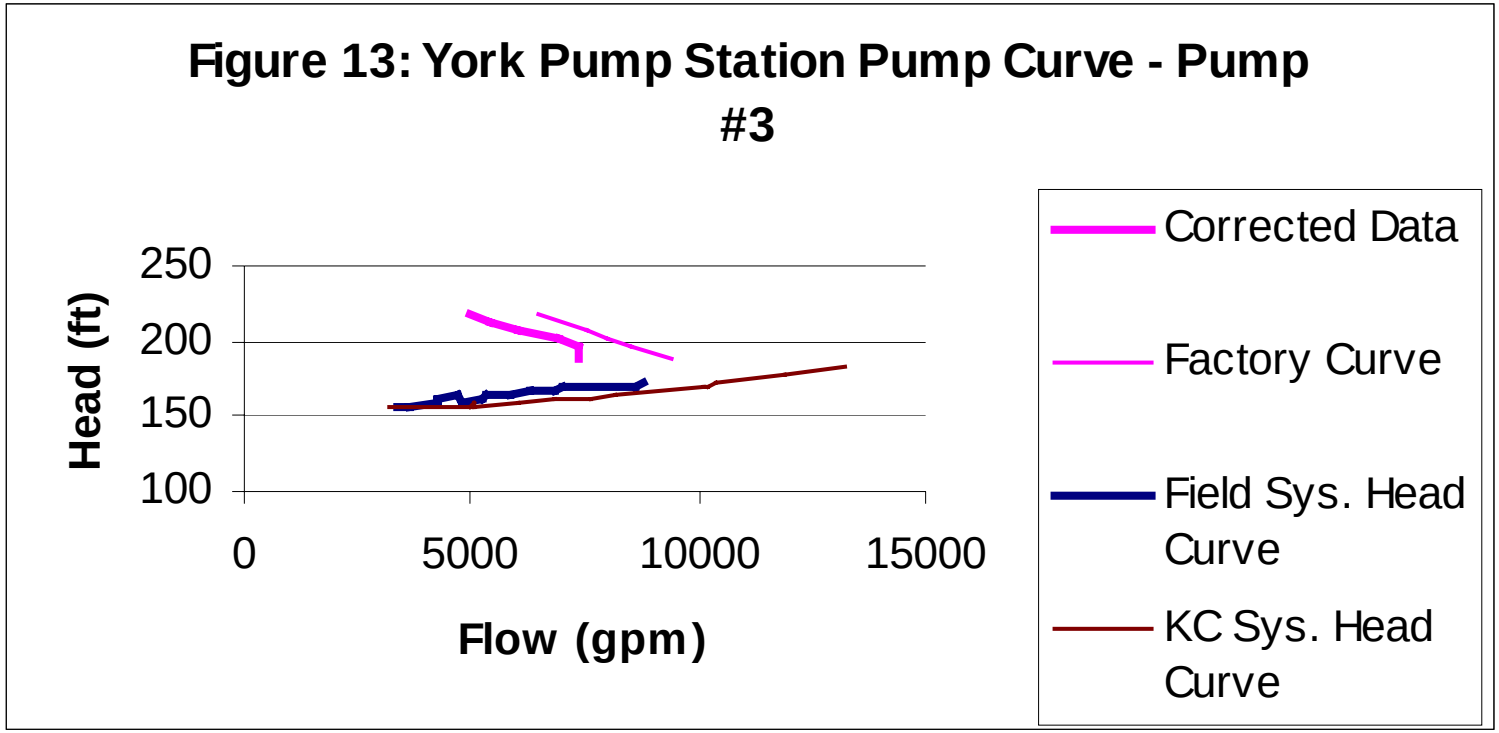
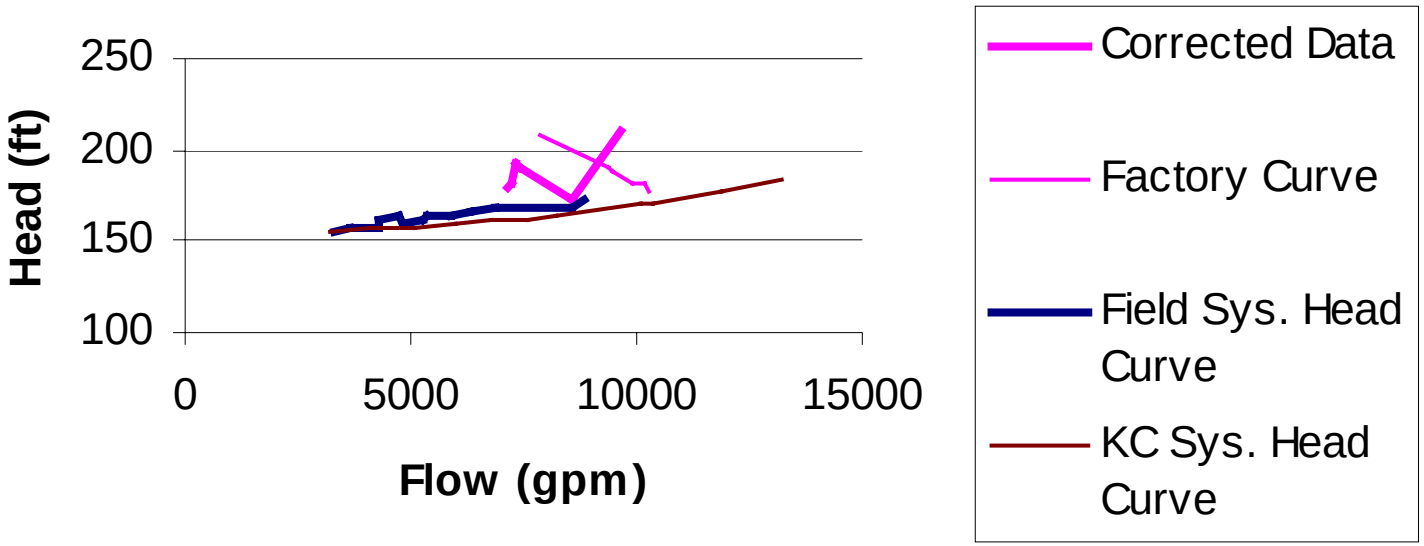


Figure 13: York Pump Station Pump Curve - Pump #3
Head (ft)
250
200
150
100
0
5000
10000
15000
Flow (gpm)
Corrected Data
Factory Curve
Field Sys. Head Curve
KC Sys. Head Curve

Figure 14: York Pump Station Pump Curve - Pump #5



7.7 York Pump Station – Observations & Recommendations:

Summarized below are the observations and recommendations for the flow, wet well elevation, and speed measurement. According to the scope of work, an error range within 10% is considered acceptable according to the Hydraulics Institute for Field Testing.

7.7.1 Flow Measurement:

Control Panel Flow vs. Portable Meter Flow:

- Pump #1 – There is good correlation between the test data and the control panel data. The average error is approximately 1.5%. Recalibration of the Pump #1 station flow meter is unnecessary.
- Pump #3 – There is not good correlation between the test data and the control panel data. The average error is approximately 11.25%. Since the station meter is a magnetic flow meter connected to the force main, and the other pumps gave acceptable readings, the test flow meter readings were probably in error. This could have been due to the location of the transducers, excessive turbulence, and/or entrained air. Follow up tests could be conducted to verify the accuracy of the data.
- Pump #5 – There is good correlation between the pump station flow meter and the test data. The average error is approximately 3.3%. There is no need to recalibrate the station flow meter. The Pump #5 station flow meter reads consistently below the test flow meter.

Control Panel Flow vs. CATAD Flow Readings:

- Pump #1 – In general, the data readings for the control panel flow and CATAD flow show good correlation. The data reading for Run #6 appears to be a bad reading. It is the only reading off by more than 10%. The average error between the control panel and CATAD flow data for all other readings was approximately 4.5%. The County may want to check the signal between the Pump #1 flow meter and the CATAD system, but it is probably not necessary.
- Pump #3 – There appears to be good correlation between the Pump #3 station flow meter signal and the CATAD system. There should be no need to check or recalibrate the Pump #3 flow meter signal with the CATAD system.
- Pump #5 – There is good correlation between the Pump #5 station flow meter signal and the CATAD system. The average error between the control panel and the CATAD system is 1.3%. There should be no need to check or recalibrate the Pump #5 flow meter signal with the CATAD system.

7.7.2 Speed Measurement

Control Panel Tachometer vs. Hand-Held Tachometer:

- Pump #1 – There is good correlation between the Pump #1 control panel speed reading and the tachometer readings taken on the pump floor. The average error between the readings was less than 1%. There is no need to recalibrate the Pump #1 speed meter on the Control Panel.
- Pump #3 – There is good correlation between the Pump #3 control panel speed readings and the tachometer readings taken on the pump floor. The average error between the control panel readings and the hand-held tachometer readings was less than 1%. Due to the low percent error it is not necessary to recalibrate the control panel tachometer for Pump #3.
- Pump #5 – The control panel speed readings and the tachometer readings for Pump #5 show good correlation. The average error between the control panel readings and the hand-held tachometer readings was less than 1%. Due to the low percent error it is not necessary to recalibrate the control panel tachometer for Pump #5.

Control Panel RPM vs. CATAD RPM:

- Pump #1 – The data between the Pump #1 control panel speed and the CATAD system show good correlation. The average error between the readings is approximately 2.5%. There is no need to check or calibrate the pump speed signal to the CATAD system for Pump #1.
- Pump #3 – There is good correlation between the Pump #3 control panel speed and the CATAD system reading. The average error between readings is approximately 1%. There is no need to calibrate the pump speed signal to the CATAD system for Pump #3.
- Pump #5 – There is no CATAD reading for Pump #5 since it is a constant speed pump.

7.7.3 Wet Well Elevation Measurement

Control Panel Wet Well Elevation vs. CATAD Wet Well Elevation:

- The plot of the control panel wet well elevation and the CATAD wet well readings show good correlation. The plot appears erratic but the percent error between the control panel wet well elevations and the CATAD wet well elevations are less than 1%. The erratic plot is due to scale of the graph. There is no need to check or calibrate the signal between the control panel wet well meter and the CATAD data system.

7.7.4 Pump Curves

Pump #1:

- The corrected flow and head data from the Pump #1 test runs approximate the slope and shape of the factory curve data. However, the corrected data from the field runs offset the factory curve data. The pumps appear to be performing below the value anticipated from the factory curve data. This could be due to pump wear.

Pump #3:

- The corrected flow and head data from the Pump #3 test runs approximate the slope and shape of the factory curve data. However, the corrected data are offset from the factory data and appear to be underperforming the anticipated factory curve values.

Pump #5:

- The field data and factory curve data do not show a good approximation of a pump curve for Pump #5. This is due to the configuration of the discharge piping and the difficulty in getting a measurement of flow from individual pumps.
- The portable flow meter had to be attached to the station discharge header due to the configuration of the discharge piping. The station magnetic flow meter is also attached to the header in the same approximate location.
- Since Pumps #4 through #6 are constant speed pumps, tests need to be performed with these pumps in tandem in order to get data at different points along the system head curve.
- Since the flow data is measuring flow from all pumps in the station discharge header, it is impossible to determine exactly how much of the flow is from the subject pump and how much is from the other pumps being run in tandem with the subject pump. This is due to pressure differences in the force main when running multiple pumps versus running on one pump at a time.
- The flow for Pump #5 was estimated by subtracting the flow for the variable speed pumps based upon their trials at approximately the same rpm as in their test runs. Only one test run was conducted with Pump #5 running alone at it's operating speed. All other trials were conducted with Pump #5 running in tandem with other pumps to affect the pressure in the force main and attempt to get other points along the pump curve. This is not accurate since the discharge flow of these pumps is likely different than when they are being run alone at the same speed due to the pressure characterisitic in the discharge header.
- However, the data collected for Pump #5 running alone and in tandem with other pumps did provide flow and pressure data for the system head curve of the York Pump Station Force Main.

SECTION 8 HIDDEN LAKE PUMP STATION

8.1 Background

The Hidden Lake Pump Station is located in the Ronald Wastewater Management District, west of Hidden Lake. It is at the corner of 10th Avenue NW and NW Innis Arden Way. The station is the primary pump station on the Boeing Creek Trunk. It receives flow from local residential connections and the discharge from several Ronald Sewer District pump stations. It discharges to the Richmond Beach Pump Station via the Boeing Creek Trunk.

8.2 Pump Station Design Information

Key design information for the Hidden Lake Pump Station is summarized in the table below.

Hidden Lake Pump Station Elevation Information (Metro Datum)

Pump Room Floor	225.14 ft
Wet Well Grating	235.50 ft (ground surface)
Motor Room Floor	N/A
Overflow Elevation	233.25 ft
Control Room Floor	235.50 ft

Hidden Lake Pump Station Pump and Motor Information

Pumps #1 and #2:	
Pump:	
Model:	Worthington, model 8FLV16, 10-inch suction, 8-inch discharge
Capacity:	2,100 gpm at 90 ft TDH and 1,145 rpm
Motor:	
Model:	Electric Machinery, frame C44SUP; rating: 75 hp at 1,180 rpm, 3-phase, 440 V, 88.5 A.

Electric Clutch	
Model:	Electric Machinery, model MDM-18; 70v, 4 A

Pump #3:	
Pump:	
Model:	Fairbanks Morse, model K3WI-070852-0, 10-diameter suction; 8-inch diameter discharge
Capacity:	2,100 gpm at 90 ft TDH and 1,450 gpm at 94 ft TDH
Motor:	
Model:	Marathon Electric, model WN 405TTD58382ANW, frame 405HPV, type TDS; rating 75 hp at 1,185 rpm, 3-phase, 440 V, 95 A
Variable Speed Drive	
Model:	Robicon Corporation, 75 hp, 480 VAC, 3-phase

8.3 Key Points and Issues

There were several key points and issues discovered during the testing and data analysis of the Hidden Lake Pump Station. They are summarized below:

- Pumps #1 & #2 are the same make and model. They were replaced in August of 1999. A single manufacturer's pump curve dated 3-14-62 was provided. The serial number on the pump curve was for Pump #2. The information from the curve was used for the Pump #1 data analysis since no other curve was available.
- Pump #3 is a different make and model than Pumps #1 and #2. It is controlled with a VFD rather than an electric clutch. The offsite facilities manual states the pump is a Fairbanks-Morse.
- There is a single station flow meter. It did not appear to be working at the time of the pump tests. There is no station clock.
- The Panametrics flow meter transducers were mounted on the 14-inch diameter force main header when testing Pumps #2 and #3. The transducers were mounted on the 10-inch diameter pump suction for Pump #1 tests due to the location of the

discharge wye and the pump station wall. There was no appropriate location to mount the transducers on the discharge side of Pump #1 that would not result in turbulence and erratic readings.

- The CATAD signals sent from the pump station to the treatment plant are wet well alarms, pump on/off status, and wet well elevation. No data is transmitted for flow or pressure.
- There is no reliable CATAD data for the pump tests run on this day. There was no useable data found when the County tried to retrieve the information from the Forney System. There are no comparisons between the field data and the CATAD data for the tests run at this pump station.
- Pump #3 normally operates as the lead pump. Pump #2 is the follow-up pump. Pump #1 does not normally operate unless there is an emergency since it has a vibration problem. When Pumps #1 and #2 were replaced in August of 1999, Pump #1 had an alignment problem. It was fixed but the problem later returned.
- The suction and discharge valving was replaced during the summer of 1999 for all three pumps.

8.4 Measuring Equipment Setup at Hidden Lake Pump Station

On the pump floor, a pressure gauge was installed on the pump discharge. The tap was located on the top of the discharge piping. The strap-on flow meter was positioned on the force main along the discharge manifold between Pumps#1 and #2 just downstream of the wall flange and upstream of the wye from Pump #1. The strap-on flow meter was positioned on the suction piping for Pump #1 since there was no adequate location on the discharge piping to locate the transducers without getting turbulence. Figure DIA – 5 in the Appendix is a schematic diagram of the piping and approximate equipment locations.

The hand-held tachometer was used on the short section of the drive shaft above the pump. The meter installation required a thickness measurement of the pipe wall where the flow transducers were mounted. This was to be taken using an ultrasonic thickness gage.

Pressure gauge readings were taken from the installed pressure gauges on the pump discharges. Pressure gauge readings were read directly and hand recorded. The elevation from the centerline of the volute to the pump floor was measured to correct the pressure gauge reading. The discharge pressure readings taken at the pump discharge were used to calculate total dynamic head.

The wet well level was recorded for each pump run from the control panel. The wet well level bubbler was checked by measuring the distance to the water surface from the grate. When the elevation was calculated using the grate elevation from the record drawings, it differed by 0.50 feet from the control panel reading. (The panel reading was higher than the field measurement).

No data logger was used.

No calibration stickers were found.

8.5 Measuring Protocol at Hidden Lake Pump Station

8.5.1 Testing Sequence

The pumps were tested in a single day (March 8, 2000). Pump #2 was tested first at several speeds. This was done to get several points along the system head curve. Pump #3 was then tested at several speeds. The portable flow meter was then switched from the 14-inch force main discharge header to the 10-inch Pump #1 suction pipe. Then tests were conducted for Pump #1.

8.5.2 Measuring Protocol – Pump Floor

Data were read on the pump floor as follows:

- Flow: the pump flow was read directly from the Panametrics flow meter data display and hand recorded.
- Pressure: the discharge pressure from the pump was read directly from the dial gauge at the pump discharge and hand recorded.
- Pump Speed: the pump speed was read from the drive shaft using the hand-held tachometer.
- Time: the time of the reading was taken from a wristwatch.

8.5.3 Measuring Protocol – Main Control Room

Data were read in the main control room as follows:

- Flow: no station flow was recorded since the station flow meter was not working.
- Pressure: The header pressure was read and recorded from a pressure gauge on the wall in the control room.
- Wet Well Elevation: the wet well elevation was read from the control panel at the time of the pump run.
- Pump Speed: the pump speed for Pumps #1 & #2 was read directly from a gauge on the control panel at the time of the pump run. The speed for Pump #3 was read directly from the VFD panel as a percent of maximum speed.
- Time: the time of the pump test and data recording was read from a wristwatch.

8.5.4 Hidden Lake Pump Station: Collected Data

This section presents and compares the data collected at the Hidden Lake Pump Station. Data were collected on the pump floor using portable measuring devices and at the control panel. No reliable data was retrieved from the CATAD system.

Table 17 presents the hand-recorded data taken on March 8, 2000. Table 18 summarizes the differences between the hand-recorded data on the pump floor and the corresponding data recorded in the control room. This gives an indication of the error present between the control panel readings and the data readings from the portable measuring devices.

Figures A-51 through A-56 in the Appendix graph and compare the data collected at the pump floor and control panel. If the data matched exactly, it would plot along a 1:1 slope on the graph. These plots show how the data compare.

Table 17: Hidden Lake Pump Station Recorded Data

Run #	Date	Time (Main Floor)	Pump #	Wet Well Elev. (ft)	Pump Down Time	Speed (rpm/%)	Disc. Press. (ft)	Time (Pump Floor)	Test Meter Flow (mgd)	Abs. Flow Var. (mgd	*Test Meter Flow (Calc) (gpm)*	Pump Press.	*Pump Press. (Calc) (ft)*	Hand-Held Tachometer (rpm)	Notes
1a	3/8/00	12:40	2	232.1	12:42	760	60	12:41	0.63		*437.5*	28.0	*64.6*	900.2	
1b	3/8/00		2	232.1	NR	760	60	12:42	0.79		*548.6*	29.0	*66.9*	900.9	
2a	3/8/00	12:43	2	231.6	12:45	1000	81	12:43	3.50		*2,430.5*	38.0	*87.7*	1170.0	
2b	3/8/00	12:45	2	228.8	12:45	1000	80	12:45	3.43		*2,381.9*	37.0	*85.4*	1170.0	
3	3/8/00	12:48	2	230.0	12:50	900	66	12:48	2.34		*1,625.0*	34.0	*78.5*	1060.0	
4	3/8/00	12:53	2	230.5	12:55	825	63	12:53	1.52	0.03	*1,055.6*	30.0	*69.2*	965.7	
5	3/8/00	1:15	3	229.8	1:17	85.10%	62	1:16	1.61		*1,118.0*	32.0	*73.9*	1011.0	Switched on between Pump # to #2 then back.
6	3/8/00	1:20	3	232.1	1:22	100.00%	73	1:21	2.81		*1,951.4*	38.0	*87.7*	1185.0	Off at 1:18, On at 1:20
7	3/8/00	1:24	3	230.1	1:26	94.70%	69	1:25	2.12		*1,472.2*	36.0	*83.1*	1121.0	
8	3/8/00	1:33	3	230.1	1:35	80.20%	60	1:33	0.82		*569.4*	31.5	*72.7*	954.3	
9	3/8/00	1:38	2+3	231.7	1:40	1000/100	92	1:39	3.78	0.03	*2,625.0*	45.5	*105.0*	1176(2),1186	Flow measurement is from Pump #3 discharge
10	3/8/00	2:20	1	230.1	2:22	810	60	2:21	1.22	0.03	*847.2*	30.0	*69.2*	957.0	
11	3/8/00	2:28	1	231.2	2:30	1040	80	2:29	3.47		*2,409.7*	39.5	*91.2*	1171.0	
12	3/8/00	2:30	1	229.8	2:32	760	58	2:31	0.55	0.02	*381.9*	29.5	*68.1*	907.0	
13	3/8/00	2:38	1	230.8		900	68	2:39	2.42		*1,680.5*	33.0	*76.2*	1040.0	

Note: Columns in Italics are calculated and were not recorded in the field

Pump #3 speed readings are percent of maximum speed (1185 rpm).

NR = No Reading

Table 18: Hidden Lake Pump Station Summary of Errors Between Pump Floor and Control Room Data Readings

Run #	Date	Pump #	Control Panel Speed (rpm)	Hand-Held Tach. (rpm)	Speed Diff (rpm)	% Difference Tachometer to Control Panel	Disch Press Ctl. Pnl (ft)	*Pump Press Portable (ft)*	Difference	% Difference Portable to Control Panel
1a	3/8/00	2	760	900.2	-140.2	-18.4%	60	*64.6*	-4.6	-7.7%
1b	3/8/00	2	760	900.9	-140.9	-18.5%	60	*66.9*	-6.9	-11.6%
2a	3/8/00	2	1000	1170.0	-170.0	-17.0%	81	*87.7*	-6.7	-8.3%
2b	3/8/00	2	1000	1170.0	-170.0	-17.0%	80	*85.4*	-5.4	-6.7%
3	3/8/00	2	900	1060.0	-160.0	-17.8%	66	*78.5*	-12.5	-18.9%
4	3/8/00	2	825	965.7	-140.7	-17.1%	63	*69.2*	-6.2	-9.9%
5	3/8/00	3	1008.4	1011.0	-2.6	-0.3%	62	*73.9*	-11.9	-19.1%
6	3/8/00	3	1185.0	1185.0	0.0	0.0%	73	*87.7*	-14.7	-20.1%
7	3/8/00	3	1122.2	1121.0	1.2	0.1%	69	*83.1*	-14.1	-20.4%
8	3/8/00	3	950.4	954.3	-3.9	-0.4%	60	*72.7*	-12.7	-21.2%
9	3/8/00	2	1000.0	1176.0	-176.0	-17.6%	92	*72.7*	19.3	21.0%
9	3/8/00	3	1185	1186.0	-1.0	-0.1%	92	*105.0*	-13.0	-14.1%
10	3/8/00	1	810	957.0	-147.0	-18.1%	60	*69.2*	-9.2	-15.4%
11	3/8/00	1	1040	1171.0	-131.0	-12.6%	80	*91.2*	-11.2	-14.0%
12	3/8/00	1	760	907.0	-147.0	-19.3%	58	*68.1*	-10.1	-17.4%
13	3/8/00	1	900	1040.0	-140.0	-15.6%	68	*76.2*	-8.2	-12.0%

Note: Columns in Italics are calculated and were not recorded in the field

8.6 Hidden Lake Pump Station – Data Analysis

The data collected during the pump runs was analyzed and corrected in order to develop pump curves. These pump curves were compared to manufacturer's pump curves and/or pump data provided by the County.

The pump data were corrected by using the pump affinity laws. These laws are used to convert/correct flow and pressure data collected at a given pump speed to a set curve speed. This is done by multiplying the square of the ratio of curve speed to pump speed to correct for head, and multiplying the ratio of curve speed to pump speed to correct for flow.

The total differential head is calculated by adding the discharge head, velocity head, and suction head; and subtracting from this total the inlet head. The suction head for the pump station is calculated by adding the minor losses and friction losses of the inlet piping. This is calculated from each pump run based upon the measured flow.

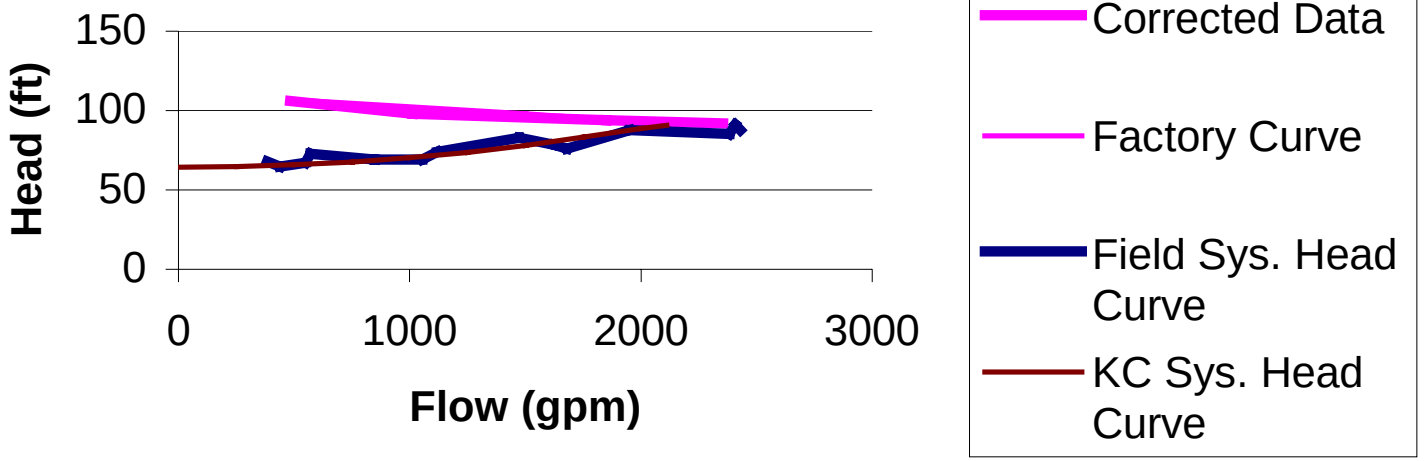
Table 19 summarizes the data correction calculations and shows the corrected pump data. All pumps have been corrected to a pump speed of 1145 rpm. This speed is within the optimal operating range for the pumps.

Figures 15 through 17 are plots of the corrected pump curves. Also shown on each figure is the factory curve generated from data provided by the pump manufacturer and/or the County's modeling database.

Table 19: Hidden Lake Pump Station – Table of Corrected Pump Data

FIELD DATA						CORRECTED DATA					CORRECTED			FLOW FROM
RUN NO.	PUMP NO.	BUBBLER LEVEL (ft)	TEST METER FLOW (gpm)	DISC. PRESS. (psi)	SPEED RPM	INLET HEAD	SUCTION HEAD	DISCH. HEAD (ft)	VELOCITY HEAD LOSS	TEST TOTAL HEAD	CURVE RPM	HEAD	FLOW	FACTORY CURVE
FIRST RUN, PUMP #2 BETWEEN 12:42 AND 12:55														
1a	2	232.1	437	28.00	900	4.0	0.1	64.7	0.2	61.0	1145	**98.7**	**556**	1400
1b	2	232.1	549	29.00	901	4.0	0.2	67.0	0.2	63.5	1145	**102.5**	**697**	980
2a	2	231.6	2,431	38.00	1170	3.5	3.2	87.8	4.8	92.4	1145	**88.5**	**2379**	2360
2b	2	228.8	2,382	37.00	1170	0.7	3.1	85.5	4.6	92.6	1145	**88.7**	**2331**	2340
3	2	230.0	1,625	34.00	1060	1.9	1.5	78.5	2.2	80.3	1145	**93.7**	**1755**	2000
4	2	230.5	1,056	30.00	966	2.4	0.6	69.3	0.9	68.5	1145	**96.3**	**1252**	1660
SECOND RUN, PUMP #3 BETWEEN 10:56 AND 11:12														
5	3	229.8	1,118	32.00	1011	2.0	0.7	73.9	1.0	73.7	1180	**100.3**	**1305**	1650
6	3	232.1	1,951	38.00	1185	4.3	2.11	87.8	3.1	88.7	1180	**88.0**	**1943**	2250
7	3	230.1	1,472	36.00	1121	2.3	1.2	83.2	1.8	83.9	1180	**92.9**	**1550**	2050
8	3	230.1	569	31.50	954	2.3	0.2	72.8	0.3	70.9	1180	**108.4**	**704**	1150
9	2+3	231.7	*675*	45.50	1186	3.9	3.8	105.1	0.4	105.4	1180	**104.3**	**672**	1375
THIRD RUN, PUMP #1 BETWEEN 2:23 AND 4:06														
10	1	230.1	847	30.00	957	2.0	0.4	69.3	0.6	68.3	1145	**97.8**	**1014**	1520
11	1	231.2	2,410	39.50	1171	3.1	3.2	91.2	4.8	96.1	1145	**91.9**	**2356**	2160
12	1	229.8	382	29.50	907	1.7	0.09	68.1	0.1	66.7	1145	**106.3**	**482**	860
13	1	230.8	1,681	33.00	1040	2.7	1.57	76.2	2.3	77.5	1145	**93.9**	**1850**	1930

Figure 15: Hidden Lake
Pump Station Pump Curve - Pump #1



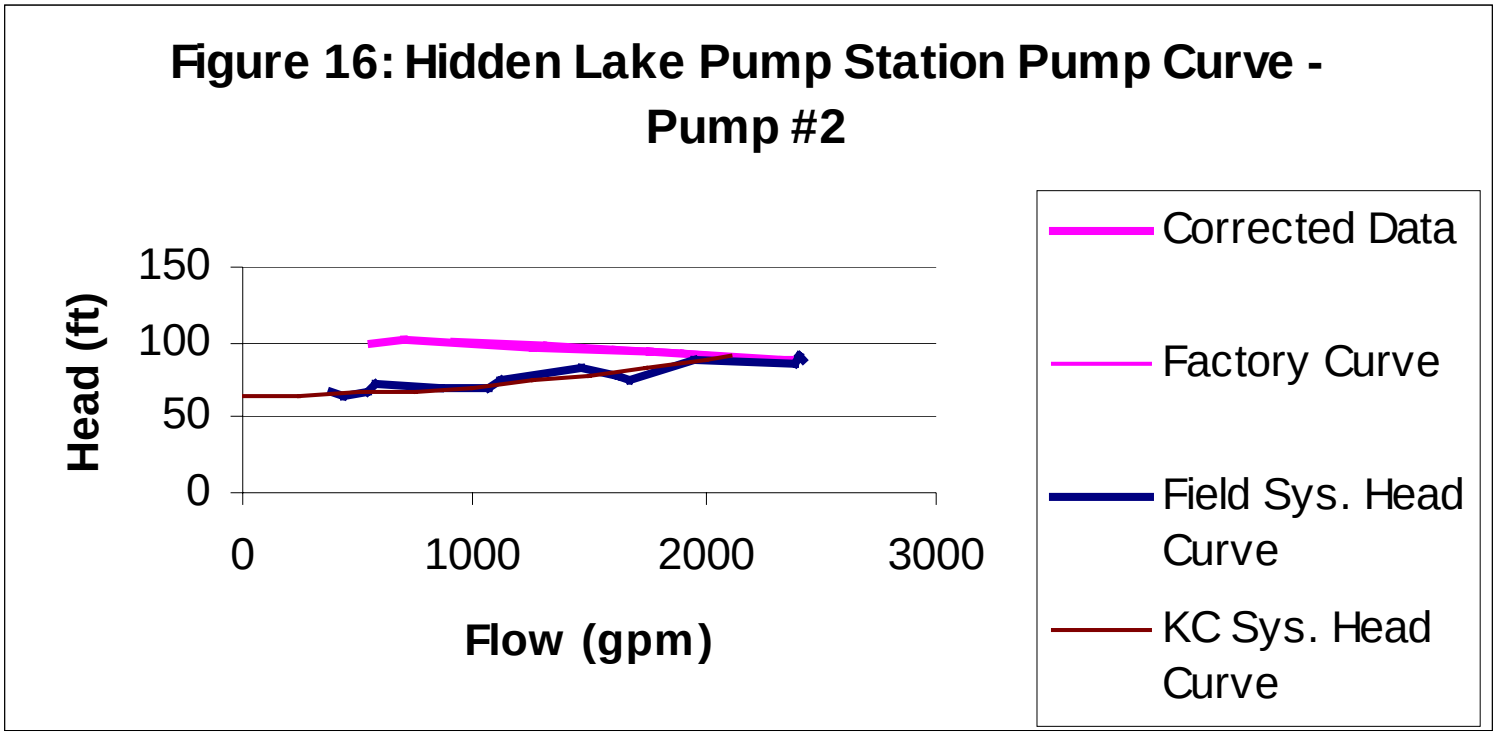
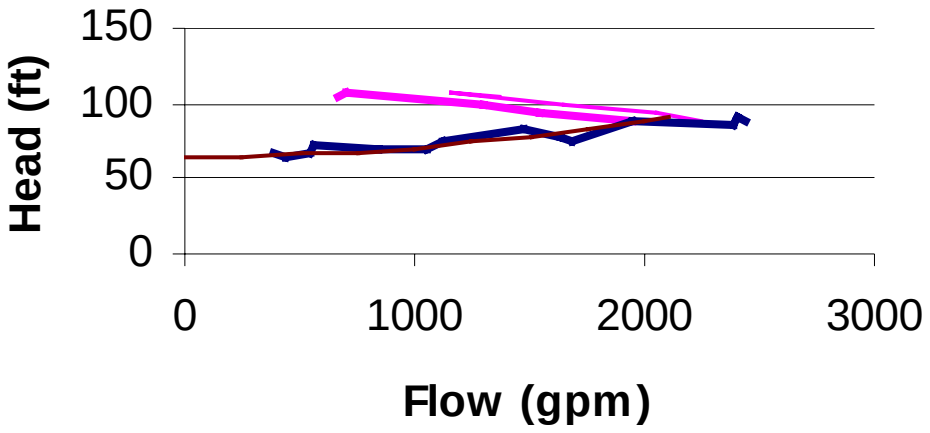


Figure 16: Hidden Lake Pump Station Pump Curve - Pump #2
Head (ft)
150
100
50
0
0
1000
2000
3000
Flow (gpm)
Corrected Data
Factory Curve
Field Sys. Head Curve
KC Sys. Head Curve

Figure 17: Hidden Lake Pump Station Pump Curve - Pump #3



8.7 Hidden Lake Pump Station – Observations & Recommendations:

Summarized below are the observations and recommendations for the flow, wet well elevation, and speed measurement. According to the scope of work, an error range within 10% is considered acceptable according to the Hydraulics Institute for Field Testing.

8.7.1 Flow Measurement:

Control Panel Flow:

- The control panel flow meter is not operational. It is recommended the flow meter be repaired and calibrated.

CATAD Flow Readings:

- There were no CATAD flow readings available from this testing. It is recommended that CATAD data be collected and compared when the pump station flow meter is repaired and calibrated.

8.7.2 Speed Measurement

Control Panel Tachometer vs. Hand-Held Tachometer:

- Pump #1 – There is not good correlation between the control panel speed reading and the tachometer readings for the tests performed on Pump #1. The average error between the readings was 16.4%. The tachometer readings were consistently higher than the control panel readings. The Pump #1 station speed meter should be recalibrated.
- Pump #2 – There is not good correlation between the control panel speed reading and the tachometer readings for the tests performed on Pump #2. The average error between the readings was approximately 17.6%. The tachometer readings were consistently higher than the control panel readings. The Pump #2 station speed meter should be recalibrated.
- Pump #3 – The control panel speed readings and the tachometer readings for Pump #3 show good correlation. The average error between the control panel readings and the hand-held tachometer readings was less than 1%. Due to the low percent error it is not necessary to recalibrate the control panel tachometer for Pump #3.

CATAD RPM Readings:

- There were no CATAD rpm readings available from this testing. It is recommended that CATAD data be collected and compared when the pump station rpm meters are recalibrated.

8.7.3 Wet Well Elevation Measurement

Control Panel Wet Well Elevation vs. CATAD Wet Well Elevation:

- The control panel wet well elevation and the field measurement differed by 0.50 feet. (The panel reading was higher than the field measurment). The wet well bubbler should be checked and recalibrated.
- There were no CATAD wet well data available for this testing. It is recommended that CATAD data be collected and compared when the pump station is recalibrated.

8.7.4 Pump Curves

Pump #1:

- The corrected flow and head data from the Pump #1 test runs approximate the slope and shape of the factory curve data. However, the corrected data from the field runs offset the factory curve data. The pumps appear to be performing below the value anticipated from the factory curve data for the higher head points. The curves approach each other and cross for lower head, higher flow points.

Pump #2:

- The corrected flow and head data from the Pump #2 test runs approximate the slope and shape of the factory curve data. However, the corrected data are offset from the factory data and appear to be underperforming the anticipated factory curve values for the higher head points. The curves approach each other and match up for the lower head, higher flow points.

Pump #3:

- The corrected flow and head data from the Pump #3 test runs approximate the slope and shape of the curve data. However, the corrected data are offset from the factory and underperform the anticipated factory curve values.

SECTION 9 NORTH BEACH PUMP STATION

9.1 Background

The North Beach Pump Station is located in north Seattle adjacent to Blue Ridge Park. It is located near the intersection of Triton Drive NW and NW 99th Street. The pump station receives flow from the North Beach Trunk serving Loyal Heights, Crown Hill, and Greenwood. Wastewater is pumped northward approximately 7,100 feet through a 14-inch force main to the Carkeek Park Pump Station and CSO Treatment Facilities.

9.2 Pump Station Design Information

Key design information for the North Beach Pump Station is summarized in the table below.

North Beach Pump Station Elevation Information (Metro Datum)

Pump Room Floor	113.75 ft
Centerline Pump Suction	116.24 ft
Wet Well Grating	124.06 ft
Motor Room Floor	123.07 ft
Overflow Elevation	122.83 ft
Control Room Floor	123.07 ft

North Beach Pump Station Pump and Motor Information

Pumps #1 and #2:	
Pump:	
Model:	Ingersol-Dresser (Worthington), model 8FLV16, 10-inch suction, 8-inch discharge
Capacity:	2,450 gpm at 86 ft TDH and 1,145 rpm
Motor:	

Model:	Electric Machinery, frame C445UP; rating: 75 hp at 1,180 rpm, 3-phase, 440 V, 88.5 A.
Electric Clutch	
Model:	Electric Machinery, model MDM-18; type BRKT; rating: 60hp, 1,130 rpm, 70v, 4 A

Pumps #3 & #4:	
Pump:	
Model:	Ingersol-Dresser (Worthington), size 5FLB16; suction : 8 in; discharge: 6-in.
Capacity:	900 gpm at 50 ft TDH and 1,170 rpm
Motor:	
Model:	Electric Machinery, frame 326UP; rating: 20 hp at 1,160 rpm, 3-phase, 440 V, 26.4 A

9.3 Key Points and Issues

There were several key points and issues discovered during the testing and data analysis of the North Beach Pump Station. They are summarized below:

- All pumps were replaced with Ingersol pumps in October, 1999. Motors and clutches were replaced in October, 1999 for Pumps #1 and #2. All suction and discharge valving was replaced in October, 1999.
- The manufacturer curves provided by the County were for Worthington Pumps of the same model number and size. These were dated June and July of 1962. These were used for comparison of the corrected pump data.
- There is no station flow meter. No flow is recorded at the pump station or by the CATAD system. CATAD records wet well level, pump status, and pump rpm.
- Force main pressure is read from a gauge on the west wall of the control room.
- Pumps #1 and #2 are variable speed pumps. Motor rpm for Pumps #1 & #2 is read on the main control panel and clutch panel.

- Pumps #3 and #4 are constant speed pumps. There is no rpm readout on the control panels for these pumps. The suction inlets for Pumps #3 and #4 are on the bottom of the wet well with the 90 degree bends parallel with the bottom. The suctions for Pumps #1 and #2 are higher with the 90-degree bend facing downward towards the bottom of the wet well.
- Some tests performed on Pumps #3 & #4 were conducted in tandem with other pumps since they are constant speed pumps. This was done in order to get flow and pressure data, which represents other operating points along the system head curve.
- We attempted to develop a pump curve from the flow and pressure readings from the Pump #3 & #4 test runs. However, there was a problem when conducting the data analysis and trying to develop the pump curves for the pumps. This problem is caused by the difficulty in determining what part of the flow measured in the force main from the pump being studied and what part is from the additional pump being operated in tandem. The flow from the pump being operated in tandem is estimated from the pump curve for that pump and subtracted from the measured flow.
- Normal operation is for Pump #3 or #4 to run individually (and intermittently) with the station in a fill-and-draw mode of operation. Pump #1 or #2 will come on with increased level in the wet well.
- When Pump #1 or #2 operates with a second pump already on-line, it appears that the clutch slows down the rpm until it cannot pump because the check valve may not open. There may not be enough capacity in the force main for two pumps to be operating at the same time.
- Once Pump #1 or #2 comes on, the operator must turn them off manually.

9.4 Measuring Equipment Setup at North Beach Pump Station

On the pump floor, a pressure gauge was installed on the pump discharge. The gauge was wired to the discharge piping and was at the same elevation as the pump volute. The tap was located on the top of the discharge piping.

The strap-on flow meter was positioned overhead on the force main between the discharge wyes for Pump #1 and Pump #2. The transducers were located very close to the wye from the Pump #1 discharge and were set up in a single-pass configuration. This location was used for testing Pumps #2, #3, & #4. For Pump #1, the test flow meter was placed on the short section of straight pipe on the pump suction, also in a single-pass configuration. This location was used because there was no room to locate the transducers downstream of the Pump #1 discharge wye. Figure DIA – 6 in the Appendix is a schematic diagram of the piping and approximate equipment locations. The pipe material programmed into the flow meter was cast iron. The pipe in this station is ductile iron. The flows recorded for Pump #1 were increased by 5% in order to account for the difference in pipe thickness between 10-inch ductile iron and 10-inch cast iron.

The hand-held tachometer was used on the section of the drive shaft above the pump. The tachometer read the reflective tape through an access door in the cover guard near the "J" joint in the shaft. The flow meter installation required a thickness measurement of the pipe wall where the flow transducers were mounted to be taken using an ultrasonic thickness gage.

Pressure gauge readings were taken from the installed pressure gauges on the pump discharges. Pressure gauge readings were read directly and hand recorded. The elevation from the centerline of the volute to the pump floor was measured to correct the pressure gauge reading. The pressure readings taken at the pump discharge were used to calculate total dynamic head.

The wet well level was recorded for each pump run from the control panel. The wet well level bubbler was checked by measuring the distance to the water surface from the grate. When the elevation was calculated using the grate elevation from the record drawings, it differed by approximately 0.20 feet from the control panel reading. (The panel reading was greater than the field measurement).

No data logger was used.

No calibration stickers were found.

9.5 Measuring Protocol at North Beach Pump Station

9.5.1 Testing Sequence

The pumps were tested in a single day (March 9, 2000). Pump #2 was tested first at several speeds. This was done to get several points along the pump curve. Pump #3 (constant speed) was then tested alone and in tandem with Pump #2 in order to get two points on the head curve. Pump #4 was also tested in the same manner. The portable flow meter was then switched from the 14-inch force main discharge header to the 10-inch Pump #1 suction pipe. Then tested were conducted for Pump #1.

9.5.2 Measuring Protocol – Pump Floor

Data were read on the pump floor as follows:

- Flow: the pump flow was read directly from the Panametrics flow meter data display and hand recorded.
- Pressure: the discharge pressure from the pump was read directly from the dial gauge at the pump discharge and hand recorded.
- Pump Speed: the pump speed was read from the drive shaft using the hand-held tachometer.
- Time: the time of the reading was taken from a wristwatch.

9.5.3 Measuring Protocol – Main Control Room

Data were read in the main control room as follows:

- Flow: no station flow was recorded since there was no station flow meter.
- Pressure: The force main pressure was read and recorded from a pressure gauge on the wall in the control room.
- Wet Well Elevation: the wet well elevation was read from the control panel at the time of the pump run.
- Pump Speed: the pump speed for Pumps #1 & #2 was read directly from two panels, the main control panel and the clutch panel. The speed for Pumps #3 & #4 were measured with the tachometer on the pump floor, but there was no panel reading since the pumps are constant speed.
- Time: the time of the pump test and data recording was read from a wristwatch.

9.6 North Beach Pump Station: Collected Data

This section presents and compares the data collected at the North Beach Pump Station. Data were collected on the pump floor using portable measuring devices and at the control panel. No reliable data was retrieved from the CATAD system.

Table 20 presents the hand-recorded data taken on March 9, 2000. Table 21 summarizes the differences between the hand-recorded data on the pump floor and the corresponding data recorded in the control room. This gives an indication of the error present between the control panel readings and the data readings from the portable measuring devices.

Figures A-57 through A-62 in the Appendix graph and compare the data collected at the pump floor and control panel. If the data matched exactly, it would plot along a 1:1 slope on the graph. These plots show how the data compare.

Table 20: North Beach Pump Station Recorded Data

Run #	Date	Time (Main Fl)	Pump #	WW El. (ft)	Speed (rpm)	Disch Press (psi)	Pump Down	Time (Pump Fl)	Test Meter Flow (mgd)	Observ Flow Var. (mgd)	*Test Meter Flow (gpm) (Calculated)*	Pump Press. (psi)	*Pump Press (ft) (Calculated)*	Hand-Held Tach. (rpm)	Notes
1	3/9/00	9:55	2	116.9	660	12.0	9:57	9:54	0.54		*375*	15.0	*34.6*	694.3	Check valve just open
2	3/9/00	10:09	2	119.5	800	18.0	10:11	10:09	1.35		*938*	21.5	*49.6*	828.3	Pump #2 off 9:58, let ww fill, #3 & #4 on briefly, #2 on 10:08
3	3/9/00	10:12	2	117.4	945	23.5	10:14	10:12	1.80	0.05	*1,248*	28.5	*65.8*	970.5	
4	3/9/00	10:24	2	118.8	1170	35.0	10:26	10:24	2.60	0.10	*1,806*	42.0	*96.9*	1186.0	Pump #2 off 10:13, let ww fill, Pump #2 on 10:23
5	3/9/00	10:34	2	118.7	1040	27.5	10:36	10:34	2.14		*1,486*	33.0	*76.2*	1056.0	Pump #2 on 10:33, unstable flow meter reading
6	3/9/00	10:36	2	116.9	1040	27.5	10:38	10:36	2.24		*1,556*	35.0	*80.8*	1057.0	Second reading on same point
7	3/9/00	10:56	3	117.3	C	16.0	10:58	10:55	1.50	0.05	*1,042*	18.5	*42.7*	1177.0	Pump #3 off 10:48, on 10:53, off 10:58
8	3/9/00	11:12	3	118.4	C	24	11:14	11:10	2.10		*1458*	27.5	*63.5*	1186	
8	3/9/00	11:12	2	118.4	900	24.0	11:14	11:10	2.10		*1,458*	28.0	*64.6*	1186	Pump #2&#3 on 11:09, pumps off 11:12
9	3/9/00	11:24	4	119.2	C	17.0	11:26	11:23	1.40		*972*	20.5	*47.3*	1179.0	Pump off 11:26
10	3/9/00	11:32	4	119.1	C	23.0	11:34	11:32	1.94	0.06	*1347*	28.0	*64.6*	1186	
10	3/9/00	11:32	2	119.1	900	23.0	11:34	11:32	1.94	0.06	*1,347*	29.0	*66.9*	925	Pumps on 11:31
11	3/9/00	2:23	1	119.0	1200	36.0	2:25	2:23	1.20	1.20	*875*	42.0	*96.9*	1185.0	Meter on disch of ds of P#1(11 through 14), Pump on 2:21,Pump off 2:25
12	3/9/00	2:33	1	118.7	700	13.0	2:35	2:33	0.70	0.70	*510*	17.0	*39.2*	695.9	Pump on 2:32, Pump off 2:34, excessive turbulence
13	3/9/00	2:39	1	119.1	880	19.5	2:41	2:38	1.20	1.20	*875*	25.0	*57.7*	876.5	Pump on 2:38, Excessive Turbulence
14	3/9/00	2:46	1	119.2	1060	29.0	2:48	2:45	0.47	0.47	*343*	34.5	*79.6*	1057.0	Excessive Turbulence
15	3/9/00	3:35	1	119.2	1060	29.0	3:37	3:34	2.77		*2,020*	34.0	*78.5*	1061.0	Flow Meter on Suction, Pump vibrating (might have been airbound)
16	3/9/00	3:43	1	118.5	700	13.0	3:45	3:43	1.03	0.05	*751*	17.5	*40.4*	693.6	Pump off 3:45
17	3/9/00	3:53	1	118.7	885	20.0	3:55	3:52	1.95	0.09	*1,422*	26	*60.0*	881.4	Pump off 3:54
18	3/9/00	4:06	1	118.4	1200	36.0	4:08	4:06	3.28	0.02	*2,392*	42.5	*98.1*	1184.0	

Note: Columns in Italics are calculated and were not recorded in the field

C = Constant Speed

Table 21: North Beach Pump Station Summary of Errors Between Pump Floor and Control Room Data Readings

Run #	Date	Pump #	Control Panel Speed (rpm)	Tachometer (rpm)	Speed Difference (rpm)	% Difference Tachometer to Control Panel	Discharge Pressure Control Panel (psi)	Pump Press Portable (psi)	Difference	% Difference Portable to Control Panel
1	3/9/00	2	660	694.3	-34.3	-5.2%	12.0	15.0	-3.0	-25.0%
2	3/9/00	2	800	828.3	-28.3	-3.5%	18.0	21.5	-3.5	-19.4%
3	3/9/00	2	945	970.5	-25.5	-2.7%	23.5	28.5	-5.0	-21.3%
4	3/9/00	2	1170	1186.0	-16.0	-1.4%	35.0	42.0	-7.0	-20.0%
5	3/9/00	2	1040	1056.0	-16.0	-1.5%	27.5	33.0	-5.5	-20.0%
6	3/9/00	2	1040	1057.0	-17.0	-1.6%	27.5	35.0	-7.5	-27.3%
7	3/9/00	3	Constant	1177.0	n/a	n/a	16.0	18.5	-2.5	-15.6%
8	3/9/00	3	Constant	1186.0	n/a	n/a	24.0	27.5	-3.5	-14.6%
8a		2	900	924.1	-24.1	-2.7%	24.0	28.0	-4.0	-16.7%
9	3/9/00	4	Constant	1179.0	n/a	n/a	17.0	20.5	-3.5	-20.6%
10	3/9/00	4	Constant	1186.0	n/a	n/a	23.0	28.0	-5.0	-21.7%
10a		2	900	925.2	-25.2	-2.8%	23.0	29.0	-6.0	-26.1%
11	3/9/00	1	1200	1185.0	15.0	1.3%	36.0	42.0	-6.0	-16.7%
12	3/9/00	1	700	695.9	4.1	0.6%	13.0	17.0	-4.0	-30.8%
13	3/9/00	1	880	876.5	3.5	0.4%	19.5	25.0	-5.5	-28.2%
14	3/9/00	1	1060	1057.0	3.0	0.3%	29.0	34.5	-5.5	-19.0%
15	3/9/00	1	1060	1061.0	-1.0	-0.1%	29.0	34.0	-5.0	-17.2%
16	3/9/00	1	700	393.6	306.4	43.8%	13.0	17.5	-4.5	-34.6%
17	3/9/00	1	885	881.4	3.6	0.4%	20.0	26.0	-6.0	-30.0%
18	3/9/00	1	1200	1184.0	16.0	1.3%	36.0	42.5	-6.5	-18.1%

9.7 North Beach Pump Station – Data Analysis

The data collected during the pump runs was analyzed and corrected in order to develop pump curves. These pump curves were compared to manufacturer's pump curves and/or pump data provided by the County.

The pump data were corrected by using the pump affinity laws. These laws are used to convert/correct flow and pressure data collected at a given pump speed to a set curve speed. This is done by multiplying the square of the ratio of curve speed to pump speed to correct for head, and multiplying the ratio of curve speed to pump speed to correct for flow.

The total differential head is calculated by adding the discharge head, velocity head, and suction head; and subtracting from this total the inlet head. The suction head for the pump station is calculated by adding the minor losses and friction losses of the inlet piping. This is calculated from each pump run based upon the measured flow.

Table 22 summarizes the data correction calculations and shows the corrected pump data. Pumps #1 & #2 have been corrected to a pump speed of 1145 rpm. Pumps #3 & #4 have been corrected to a pump speed of 1170 rpm. These speeds are within the optimal operating ranges for the pumps.

Figures 18 through 21 are plots of the corrected pump curves. Also shown on each figure is the factory curve generated from data provided by the pump manufacturer and/or the County's modeling database.

Table 22: North Beach Pump Station – Table of Corrected Pump Data

		FIELD DATA					CORRECTED DATA					CORRECTED			FLOW FROM
RUN NO.	PUMP NO.	BUBBLER LEVEL (ft)	TEST METER FLOW (gpm)	DISC. PRESS. (psi)	SPEED RPM		INLET HEAD	SUCTION HEAD	DISCH. HEAD (ft)	VELOCITY HEAD LOSS	TEST TOTAL HEAD	CURVE RPM	HEAD	FLOW	FACTORY CURVE
FIRST RUN, PUMP #2 BETWEEN 9:55 AND 10:36															
1	2	116.9	375	15.00	694		-0.1	0.1	34.7	0.1	34.9	1145	**95.0**	**618**	1800
2	2	119.5	937	21.50	828		2.5	0.5	49.7	0.7	48.4	1145	**92.5**	**1296**	2050
3	2	117.4	1,250	28.50	971		0.4	0.9	65.8	1.3	67.6	1145	**94.1**	**1475**	1900
4	2	118.8	1,806	42.00	1186		1.8	1.9	97.0	2.7	99.8	1145	**93.0**	**1743**	2000
5	2	118.7	1,486	33.00	1056		1.7	1.3	76.2	1.8	77.6	1145	**91.3**	**1611**	2150
6	2	116.9	1,556	35.00	1057		-0.1	1.5	80.9	2.0	84.3	1145	**99.0**	**1685**	1450
SECOND RUN, PUMP #3 BETWEEN 10:56 AND 11:12															
7	3	117.3	1,177	18.50	1177		0.9	1.8	42.7	3.9	47.5	1170	**47.0**	**1170**	1130
8	3	118.4	*258*	27.50	1186		2.0	3.39	63.5	0.2	65.1	1170	**63.4**	**255**	220
THIRD RUN, PUMP #4 BETWEEN 11:24 AND 11:32															
9	4	119.2	972	20.50	1179		2.7	6.4	47.4	2.7	53.7	1170	**52.9**	**965**	880
10	4	119.1	*147*	28.00	1186		2.6	2.9	64.7	0.1	65.0	1170	**63.3**	**145**	230
FOURTH RUN, PUMP #1 BETWEEN 2:23 AND 4:06															
11	1	119.0	875	42.00	1185		2.2	0.5	97.0	0.1	95.4	1145	**89.1**	**845**	2350
12	1	118.7	510	17.00	696		1.9	0.2	39.3	0.0	37.6	1145	**101.8**	**840**	1250
13	1	119.1	875	25.00	877		2.3	0.5	57.8	0.1	56.1	1145	**95.7**	**1143**	1750
14	1	119.2	343	34.50	1057		2.4	0.07	79.7	0.0	77.4	1145	**90.8**	**371**	2200
15	1	119.2	2,020	34.00	1061		2.4	2.43	78.5	0.6	79.2	1145	**92.2**	**2180**	2050
16	1	118.5	751	17.50	694		1.7	0.35	40.4	0.1	39.2	1145	**106.8**	**1240**	900
17	1	118.7	1,422	26.00	881		1.9	0.35	60.1	0.3	58.8	1145	**99.3**	**1847**	1400
18	1	118.7	2,392	42.50	1184		1.9	3.39	98.2	0.8	100.5	1145	**94.0**	**2313**	1900

Note: Flow values in Italics are estimated.

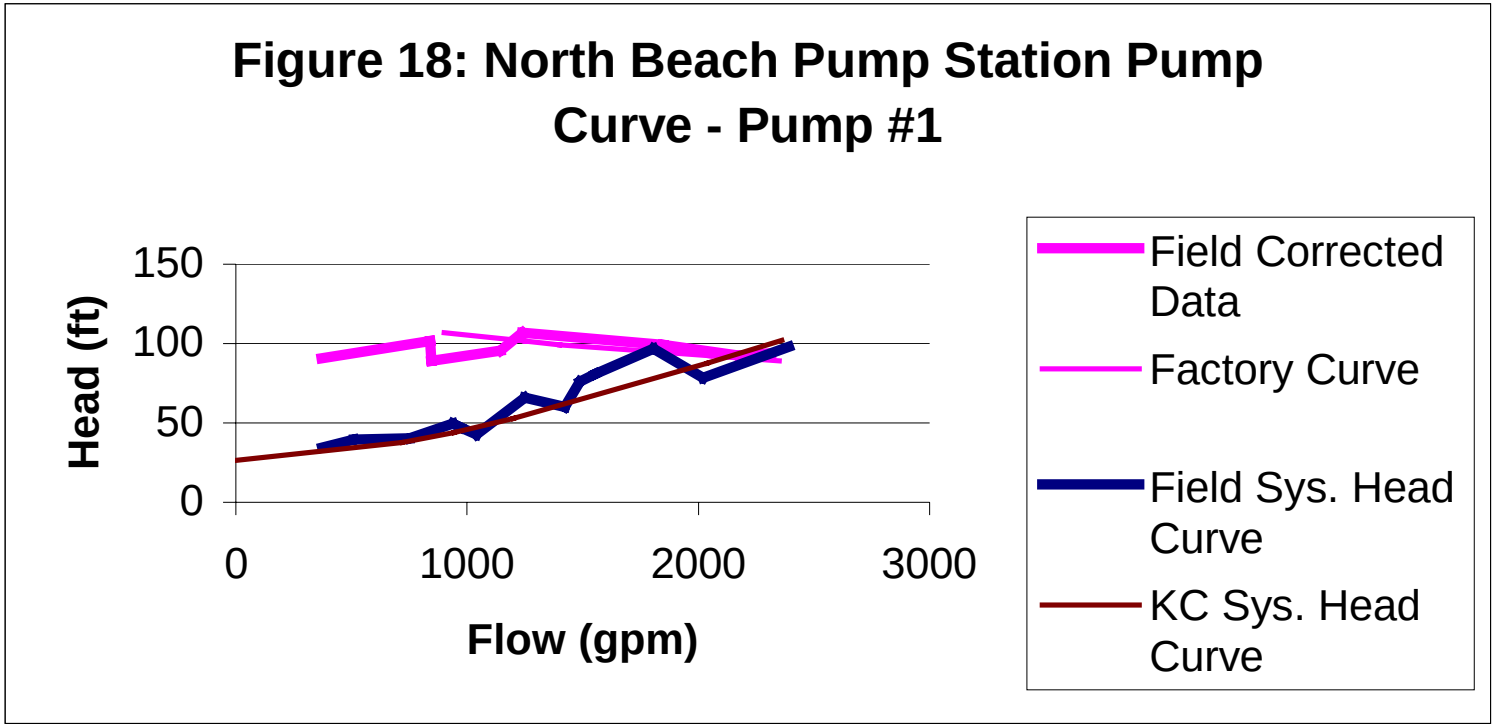
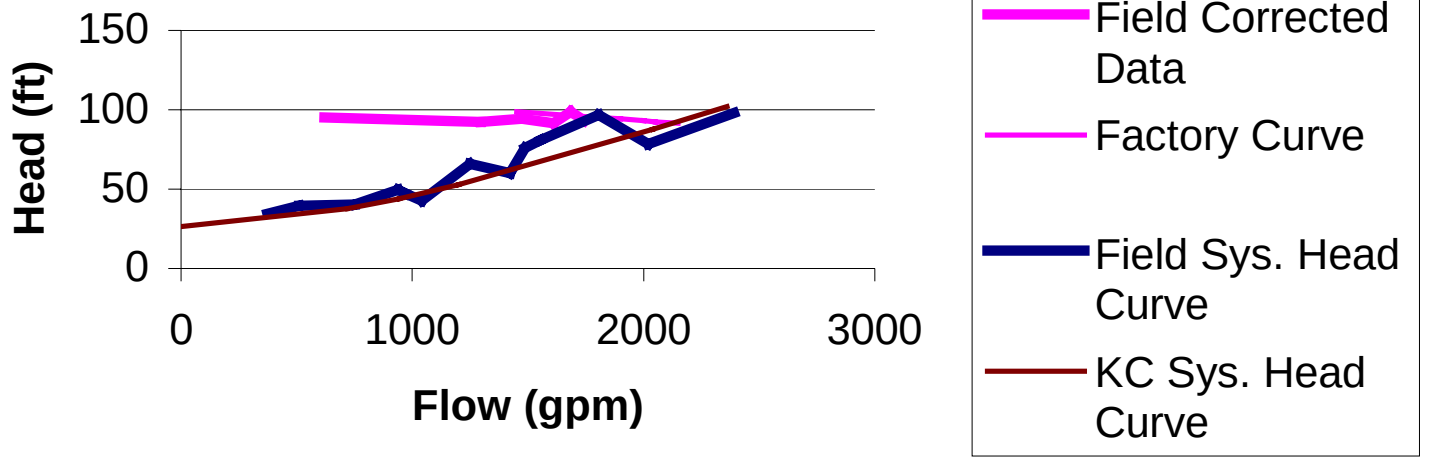


Figure 18: North Beach Pump Station Pump Curve - Pump #1
Head (ft)
150
100
50
0
0
1000
2000
3000
Flow (gpm)
Field Corrected Data
Factory Curve
Field Sys. Head Curve
KC Sys. Head Curve

Figure 19: North Beach Pump Station Pump Curve - Pump #2



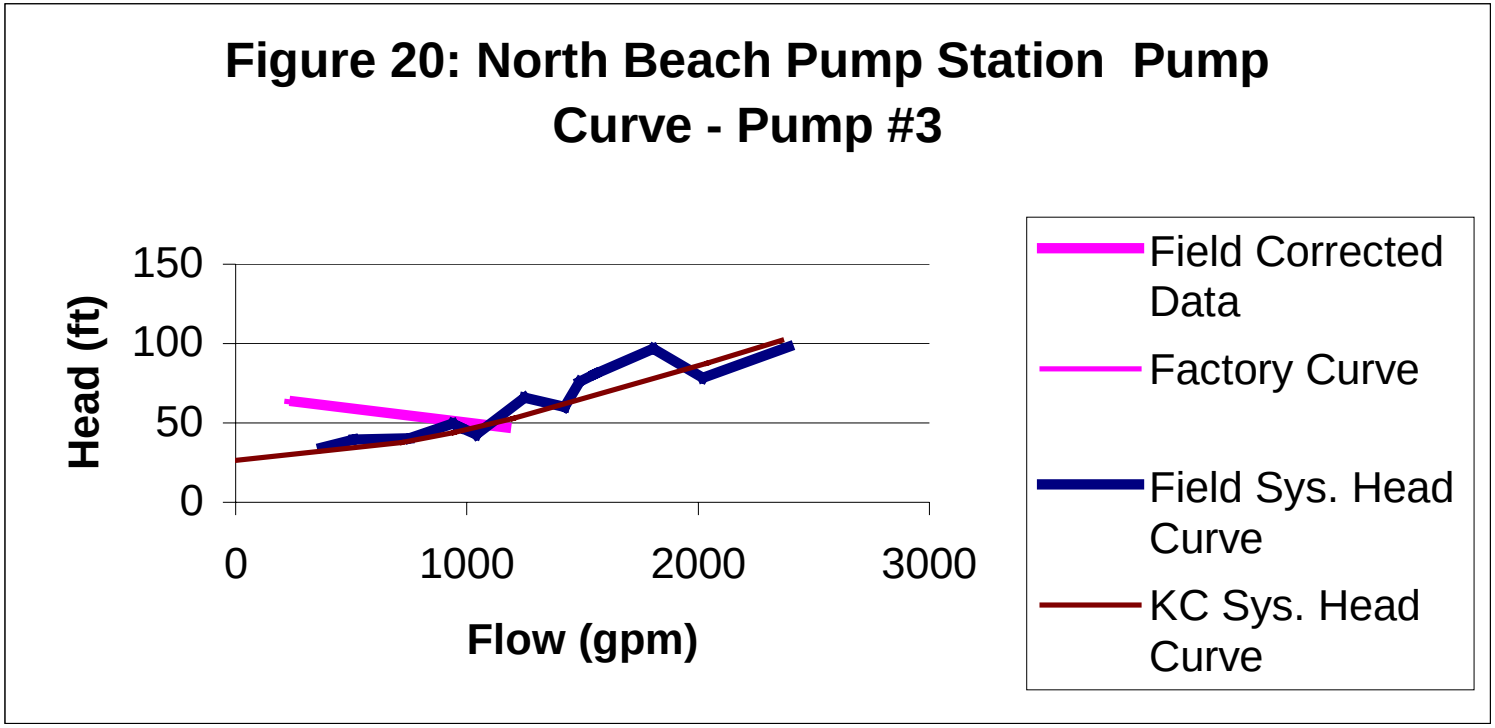
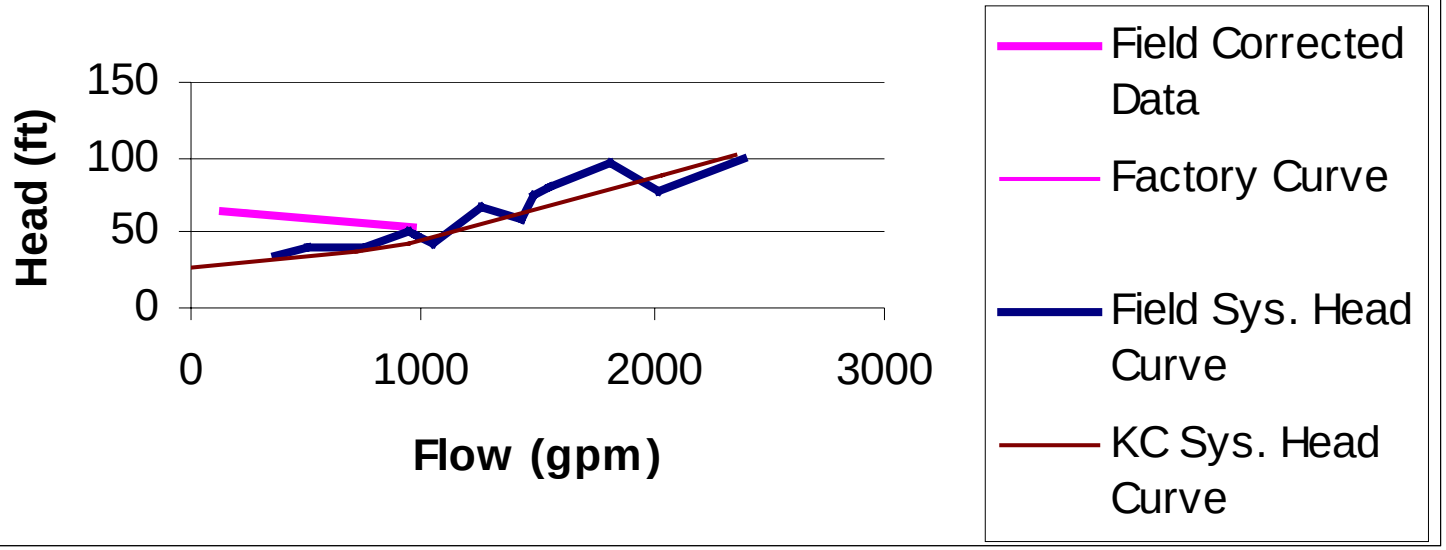


Figure 20: North Beach Pump Station Pump Curve - Pump #3
Head (ft)
150
100
50
0
0
1000
2000
3000
Flow (gpm)
Field Corrected Data
Factory Curve
Field Sys. Head Curve
KC Sys. Head Curve

Figure 21: North Beach Pump Station Pump Curve - Pump #4



9.8 North Beach Pump Station – Observations & Recommendations:

Summarized below are the observations and recommendations for the flow, pressure, wet well elevation, and speed measurement. According to the scope of work, an error range within 10% is considered acceptable according to the Hydraulics Institute for Field Testing.

9.8.1 Flow Measurement:

Control Panel Flow:

- There is no control panel flow meter. The County may want to consider installing a station flow meter to more accurately monitor the flows from the pump station.

CATAD Flow Readings:

- There were no CATAD flow readings available from this testing. It is recommended that CATAD data be collected and compared with portable flow meter readings when the equipment and instrumentation at this pump station is checked and recalibrated.

9.8.2 Speed Measurement

Control Panel Tachometer vs. Hand-Held Tachometer:

- Pump #1 – There is good correlation between the control panel speed reading and the tachometer readings for the tests performed on Pump #1. All test runs had an error at or below 1% except for one reading which was off by approximately 43.8%. This was probably a faulty data reading. The average error between the readings was 6% including the presumed faulty data reading. The average error without the questionable data reading was approximately 0.6%. The Pump #1 station speed meter does not need to be checked or recalibrated.
- Pump #2 – There is good correlation between the control panel speed reading and the tachometer readings for the tests performed on Pump #2. The average error between the readings was approximately 2.65%. The tachometer readings consistently higher than the control panel readings. The Pump #2 station speed meter does not need to be recalibrated.
- Pumps #3 & #4 – There are no control panel readings for these pumps since they are constant speed pumps.

CATAD RPM Readings:

- There were no CATAD rpm readings available from this testing. It is recommended that CATAD data be collected and compared after other equipment and instrumentation is checked and recalibrated.

9.8.3 Wet Well Elevation Measurement

Control Panel Wet Well Elevation vs. CATAD Wet Well Elevation:

- There were no CATAD wet well data available for this testing. It is recommended that CATAD data be collected and compared when the pump station is recalibrated.

9.8.4 Pressure Measurement

Control Panel Pressure vs. Portable Pressure Gauge:

- Pump #1 – The pressure readings between the portable gauge and the control panel for the Pump #1 tests did not show good correlation. The average error between readings was approximately 24%. The control panel reading was consistently below the gauge pressure reading. The portable meter readings are believable since the gauge was recently purchased and is traceable to NBS. The control panel pressure gauge should be checked and recalibrated.
- Pump #2 – The pressure readings between the portable gauge and the control panel for the Pump #2 test did not show good correlation. The average error between readings was approximately 22%. The control panel reading was consistently below the gauge pressure reading. The control panel pressure gauge should be checked and recalibrated.
- Pump #3 – The pressure readings between the portable gauge and the control panel for the Pump #3 test did not show good correlation. The average error between readings was approximately 15%. The control panel reading was consistently below the gauge pressure reading. The control panel pressure gauge should be checked and recalibrated.
- Pump #4 – The pressure readings between the portable gauge and the control panel for the Pump #4 test did not show good correlation. The average error between readings was approximately 21%. The control panel reading was consistently below the gauge pressure reading. The control panel pressure gauge should be checked and recalibrated.

9.8.5 Pump Curves

Pump #1:

- The corrected flow and head data from the Pump #1 test runs do not approximate the factory pump curve. The corrected data appears to be erratic and do not follow the shape and direction of the factory curve over the entire range of flow tested. This could be due to the location of the flow transducers on the pump suction, excessive turbulence experienced during the testing, and soundspeed errors due to entrained air in the pipeline. Erratic flow readings occurred during the pump tests and at times it was difficult to get a steady flow reading from the portable flow meter.

Pump #2:

- The corrected flow and head data from the Pump #2 test runs do not approximate the factory pump curve. The corrected data appears to be erratic and do not follow the shape and direction of the factory curve over the entire range of flow tested. This could be due to the location of the flow transducers on the discharge manifold and the close location to the discharge wyes of the adjacent pumps. There were unstable flow readings on the meter and in some low flow tests the check valve would rock making it difficult to get a steady flow reading.

Pump #3:

- The corrected flow and head data from the Pump #3 test runs approximate the slope and shape of the factory curve data. Since this is a constant speed pump we were able to get only two data points to approximate the curve. One with the pump running alone and another with Pump #2. The flow from Pump #2 was estimated and subtracted from the flow meter reading when correcting the data.

Pump #4:

- The corrected flow and head data from the Pump #4 test runs approximate the slope and shape of the factory curve data. Since this is a constant speed pump we were able to get only two data points to approximate the curve. One with the pump running along and another with Pump #2. The flow from Pump #2 was estimated and subtracted from the flow meter reading when correcting the data.

SECTION 10 MATTHEWS PARK PUMP STATION

10.1 Background

The Matthews Park Pump Station is located along the west shore of Lake Washington inside Matthews Beach Park. The station receives flow from the Kenmore Pump Station through the Lake Line and from the Thornton Creek Trunk and Lake City Trunk from the west. The station pumps through 1,100 feet of parallel 42-inch and 54-inch diameter force mains to the north portal of the Lake City Tunnel where it continues to the Lake City Regulator Station. Pumps #1, #2, and #3 normally pump through a 36-inch manifold in the station to the 42-inch force main. Pump #4 discharges through a 48-inch header to a 54-inch force main. The 36-inch and 48-inch manifold can be connected via an intertie pipe and a motor operated valve.

10.2 Pump Station Design Information

Key design information for the Matthews Park Pump Station is summarized in the table below.

Matthews Park Pump Station Elevation Information

Pump Room Floor	83.00 ft
Wet Well Grating	101.00 ft
Motor Room Floor	100.92 ft
Overflow Elevation (flap gates in Lake Line when interceptor because surcharged 12-inches above Lake's surface level).	115.00 ft
Control Room Floor	134.37
Equipment Bay	132.0

Matthews Park Pump Station Pump and Motor Information

Pump #1:	
Pump:	
Model:	Fairbanks-Morse, model 5712

Capacity:	9,700 gpm at 77.1 ft TDH, 705 rpm, 20-inch suction, 20-inch discharge
Impeller Size:	20-inch
Motor:	
Model:	Fairbanks-Morse, synchronous, frame 804, type TZDU
Rating:	250 hp, 720 rpm, 4,000V, 28.9 A, 3-phase
Electric Clutch	
Model:	Electric Machinery, model MDS-27-E,
Rating:	220 hp, 720 rpm, 190 V, 12.8 A, Slip 2.1 percent
Discharge Valve	Willamette Iron & Steel, 20-inch hydraulic-operated ball valve
Pump #2:	
Pump:	
Model:	Fairbanks-Morse, model 5712
Capacity:	20,250 gpm at 78.7 ft TDH, 585 rpm, 30-inch suction, 24-inch discharge
Impeller Size:	30.125-inches (calculated)
Motor:	
Model:	Fairbanks-Morse, synchronous, frame IV-16, Type TZDU
Rating:	500 hp, 600 rpm, 4,000 V, 57 A, 3-phase
Electric Clutch	
Model:	Electric Machinery, model MDS-37-G
Rating:	475 hp, 600 rpm, 190 V, 22 A, slip: 2.5 percent
Discharge Valve	Willamette Iron & Steel, 24-inch hydraulic-operated ball valve

Pump #3:	**Diesel Driven Standby Generator**
Pump:	
Model:	Fairbanks-Morse, model 5712
Capacity:	39,200 gpm at 85 ft TDH, 450 rpm, 36-inch suction, 36-inch discharge
Impeller Size:	36-inches
Motor:	
Model:	Fairbanks-Morse, synchronous, frame VI-12, Type TZDU
Rating:	900 hp, 450 rpm, 4,000 V, 102 A, 3-phase
Direct Current Generator (exciter)	
Model:	Fairbanks-Morse type DGZDOU, frame DX1304
Rating:	7.5 Kw AT 450 RPM, 125 A
Discharge Valve	Willamette Iron & Steel, 36-inch hydraulic-operated ball valve
Pump #4	**Not Tested**
Model	Worthington, Mixflo centrifugal pump, type MNZ-33
Capacity	22,200 gpm at 76 ft TDH, 705 rpm; 24-in suction, 24-inch discharge
Motor	
Model	Ideal Electric, brushless synchronous motor, type SMVB
Rating	600 hp, 720 rpm, 4,160 V, 66A, 3-phase
DC Generator	
Model	Ideal Electric, type FRBA, brushless exciter
Rating	9.0 kW, 125 V, 72 A, 720 rpm

Discharge Valve	
Model	Pratt, 24-in double seat #150, E-LOK style, rubber-seated ball valve
Hydraulic Cylinder	MDT-5, 3.25-in. x 11-in. cylinder operator with hand jack.

10.3 Key Points and Issues

There were several key points and issues discovered during the testing and data analysis of the Matthews Park Pump Station. They are summarized below:

- Tests were conducted over two days. The first day of testing was on December 9, 1999. Pumps #1 & #2 were tested on this day. Pump #3 was tested on March 15, 2000.
- Maintenance was being performed on Pump #3 during the tests conducted in December. It was not possible to obtain flow readings when the portable flow meter was installed on the discharge for Pump #4 because the discharge piping had a reinforced mortar lining.
- There are permanent pressure gauges plumbed into the suction and discharge lines of each pump. The suction gauges for Pumps #1, #2, & #3 were not giving any readings when the pumps were operating. These suction gauges were positive pressure gauges and could not provide negative pressure readings during pump tests. The suction gauge for Pump #4 provided for both positive and negative pressure readings.
- A test pressure gauge was attached to a tap in the discharge of each pump for the pump tests.
- Calibration stickers were found on the Motor Room station pressure transducer on the 36-inch force main (JL, 8-19-99), and on the Pump Room discharge pressure gauges on Pumps #1, #2, #3, & #4 (JMI, 5-31-94).

10.4 Measuring Equipment Setup at Matthews Park Pump Station

On the pump floor, a pressure gauge was installed on the pump discharge flange. The tap was located on the top of the discharge flange. The pressure gauge was positioned at the same elevation as the discharge centerline. The elevation from the centerline of the volute to the pump floor was measured to correct the pressure gauge reading. The discharge pressure was used to calculate total dynamic head.

The strap-on flow meter was first positioned on the discharge of Pump #1. Then the meter was positioned on the discharge of Pump #2. Measurements were attempted on the discharge of Pump #4 but were unsuccessful due to the reinforced mortar lining. On another day the meter was positioned on the 36-inch force main for tests on Pump #3. The transducers were positioned in a single pass configuration. The meter installation required paint to be chipped from the force main and a thickness measurement of the pipe wall where the flow transducers were mounted was taken. Figure DIA – 7 in the Appendix is a schematic diagram of the piping and approximate equipment locations.

Reflective tape was placed on the drive shaft of each pump tested near the packing above the pump.

The wet well level was recorded for each pump run from the control panel. The wet well level bubbler was checked by measuring the distance to the water surface from the grate. When the elevation was calculated using the grate elevation from the record drawings, it was off from the control panel elevation by 0.9 feet. (Panel reading was less than field measurement).

No data logger was used.

10.5 Measuring Protocol at Matthews Park Pump Station

10.5.1 Testing Sequence

Pumps #1 and #2 were tested on December 9, 1999. Pump #3 was tested on March 15, 2000. Pump #1 was tested alone at several speeds. This was done to get several points along the pump and system head curves. Pump #2 was then tested at several speeds. And finally Pump #3 was tested alone at several speeds. Pump #4 was not tested because we were not able to get readings on the test flow meter when the pump was operating (County personnel thought that thicker cement lining of the discharge pipe may have prevented the flow meter from operating properly). No pumps were run in tandem.

10.5.2 Measuring Protocol – Pump Floor

Data were read on the pump floor as follows:

- Flow: the pump flow was read directly from the Panametrics flow meter data display and hand recorded.
- Pressure: the discharge pressure from the pump was read directly from the dial gauge and hand recorded.
- Pump Speed: the pump speed was read from the drive shaft using the hand-held tachometer.
- Time: the time of the reading was taken from a wristwatch that was compared to the control panel clock.

10.5.3 Measuring Protocol – Main Control Room

Data were read in the main control room as follows:

- Flow: the total station flow, 48-inch force main flow, and 54-inch force main flow was read directly from the control panel.
- Pressure: the force main head was read directly from the control panel.
- The Lake City tunnel water elevation was read directly from the control panel.
- Wet Well Elevation: the wet well elevation was read from the control panel at the time of the pump run.
- Pump Speed: the pump speed was read directly from the control panel at the time of the pump run. The pumps were run at different speeds to obtain the desired points on the system head curve.
- Time: the time of the reading was read from the control panel.

10.6 Matthews Park Pump Station: Collected Data

This section presents and compares the data collected at the Matthews Park Pump Station. Data were collected on the pump floor using portable measuring devices, at the control panel, and from the CATAD system.

Table 23 presents the hand-recorded data taken on December 9th and March 15th. Table 24 summarizes the differences between the hand-recorded data on the pump floor and the corresponding data recorded in the control room. This gives an indication of the error present between the control panel readings and the data readings from the portable measuring devices.

Table 25 summarizes and compares the pump station data and CATAD data. The table compares pump-on time, wet well elevation, pump flow, and pump speed.

Figures A-63 through A-75 graph the data collected at the pump floor, control panel, and CATAD system. If the data matched exactly, it would plot along a 1:1 slope on the graph. These plots show how the data compare.

Table 23: Matthews Park Pump Station Recorded Data

	Date	Time	Pump	Panel Flow	Panel Flow	Total	FM	Lake City	Speed	Wet Well	Time	Test Meter	Flow	Test	*Test*	Station	*Station*	Tach.
#		(Floor)	#	48" FM (MGD)	54" FM (MGD)	(MGD)	Head (ft)	Level (ft)	(rpm)	Elev. (ft.)	(Pump)	(gpm)	Var.	(psi)	*(ft)*	(psi)	*(ft)*	(rpm)
													(gpm)					
Tests Run on December 9, 1999																		
1	12/9/99	11:24	1	23.50	-	23.5	46.0	158.0	710	93.5	11:24	9,800	-	34.00	*78.47*	8.10	*18.694*	706.0
2	12/9/99	11:36	1	24.00	-	24.0	46.0	158.0	710	95.4	11:36	10,000	-	34.00	*78.47*	8.10	*18.694*	706.1
3	12/9/99	11:39	1	17.50	-	17.5	46.0	158.0	670	95.5	11:39	7,500	50	34.00	*78.47*	8.10	*18.694*	661.2
4	12/9/99	11:43	1	10.00	-	10.0	46.0	158.0	630	95.9	11:43	3,850	-	34.00	*78.47*	8.10	*18.694*	617.9
5	12/9/99	11:53	1	7.00	-	7.0	46.0	158.0	610	97.0	11:53	3,500	200	34.00	*78.47*	8.10	*18.694*	604.0
6	12/9/99	12:29	2	40.00	-	40.5	46.5	158.0	600	96.1	12:29	20,500	-	34.00	*78.47*	-	-	592.7
7	12/9/99	12:34	2	38.00	-	39.0	47.0	158.0	570	94.9	12:34	17,000	100	34.00	*78.47*	-	-	566.0
8	12/9/99	12:38	2	36.50	-	37.0	47.0	158.0	550	95.0	12:39	16,500	-	34.00	*78.47*	-	-	547.0
9	12/9/99	12:42	2	31.00	-	32.0	47.0	158.0	530	95.4	12:42	15,000	20	34.00	*78.47*	-	-	528.5
10	12/9/99	12:47	2	28.00	-	28.5	47.0	158.0	510	95.7	12:46	14,000	-	34.00	*78.47*	-	-	513.0

Tests Run on March 15, 2000

Run	Date	Time	Pump	Control Panel	Control Panel	Total	FM	Lake City	Speed	Wet Well	Time	Test Meter	Flow	*Test*	Test	*Test*	Station	*Statio*	Tach	Notes
		(Main	#	48" FM (MGD)	54" FM (MGD)	(MGD)	Head (ft)	(ft)	(rpm)	Elev. (ft.)	(Pump	(MGD)	Var.	*(gpm)*	(psi)	*(ft)*	(psi)	*(ft)*	(rpm)	
1	3/15/00	9:56	3	50+	15	64	41	150.5	500	94.5	9:56	42.0		*29166*	37.0	*85.396*	36.5	*84.242*	472.9	Lost signal on
2	3/15/00	10:04	3	47	15	63	40	150.5	433	92.2	10:04	26.0		*18055*	34.5	*79.626*	34.0	*78.472*	394.3	Lowered
3	3/15/00	10:11	3	14	10	25	40	150.5	362	96.7	10:12	9.0		*6250*	33.0	*76.164*	32.0	*73.856*	332.2	Raised speed
4	3/15/00	10:18	3	33	10	43	40	150.5	395	97.1	10:18	21.4		*14861*	34.0	*78.472*	33.0	*76.164*	362.5	Raised speed
					0	33														
5	3/15/00	10:27	3	50+	17	70	40	150.5	475	92.1	10:28	35.3		*24514*	36.0	*83.088*	35.5	*81.934*	434.7	Velocity
					0	58														
6	3/15/00	10:49	3	50	10	66	40	150.5	500	92.6	10:49	45.0	+/-3.0	*31250*	38.0	*87.704*	37.0	*85.396*	458.8	Lowered
				0	0	5														
7	3/15/00	10:57	3	18	10	31	40	150.5	370	93.2	10:57	11.0	+/-0.5	*7639*	33.0	*76.164*	32.0	*73.856*	343.6	Flow meter
					0	20														
8	3/15/00	11:03:3	3	49	12	64	40	150.5	435	93.5	11:04	30.2	+/-2.0	*20972*	34.5	*79.626*	34.0	*78.472*	397.9	Lowered
					0	55														
9	3/15/00	11:09:3	3	29	16	43	40	150.5	395	93.6	11:10	19.6	+/-0.6	*13611*	33.5	*77.318*	32.5	*75.01*	361.3	Raised speed
					0	30														
10	3/15/00	11:15	3	50	12	70	40	150.5	475	92.5	11:16	39.8	+/-0.5	*27639*	36.0	*83.088*	35.5	*81.934*	434.3	Pump #2 on
					0	59														

Notes: Columns in Italics are calculated and were not recorded in the field

Shaded area is not accurate; flow transducers were not in position.

Station flow meters fluctuated; some runs show two groups of data reflecting these fluctuations.

Table 24: Matthews Park Pump Station Summary of Errors Between Pump Floor and Control Room Data Readings

Run #	Date	Pump #	Control Panel Flow 48" FM (MGD)	Control Panel Flow 54" FM (MGD)	Total Flow (MGD)	Test Meter Flow (MGD)	Flow Diff (MGD)	% Diff Meter to Control Panel	Test Disch (psi)	Station Disch. (psi)	Diff (psi)	% Diff to Test to Station	Speed (rpm)	Tach. (rpm)	Diff (rpm)	% Diff to Tach. to Control Panel
Tests Run on December 9, 1999																
1	12/9/99	1	23.50	-	23.5	14.1	9.4	39.9%	34.00	8.10	-25.90	-320%	710	706.0	4.0	1%
2	12/9/99	1	24.00	-	24.0	14.4	9.6	40.0%	34.00	8.10	-25.90	-320%	710	706.1	3.9	1%
3	12/9/99	1	17.50	-	17.5	10.8	6.7	38.3%	34.00	8.10	-25.90	-320%	670	661.2	8.8	1%
4	12/9/99	1	10.00	-	10.0	5.5	4.5	44.6%	34.00	8.10	-25.90	-320%	630	617.9	12.1	2%
5	12/9/99	1	7.00	-	7.0	5.0	2.0	28.0%	34.00	8.10	-25.90	-320%	610	604.0	6.0	1%
6	12/9/99	2	40.00	-	40.5	29.5	10.5	26.2%	34.00	-			600	592.7	7.3	1%
7	12/9/99	2	38.00	-	39.0	24.5	13.5	35.6%	34.00	-			570	566.0	4.0	1%
8	12/9/99	2	36.50	-	37.0	23.8	12.7	34.9%	34.00	-			550	547.0	3.0	1%
9	12/9/99	2	31.00	-	32.0	21.6	9.4	30.3%	34.00	-			530	528.5	1.5	0%
10	12/9/99	2	28.00	-	28.5	20.2	7.8	28.0%	34.00	-			510	513.0	-3.0	-1%

Tests Run on March 15, 2000

Run #	Date	Pump #	Control Panel Flow 48" FM (MGD)	Control Panel Flow 54" FM (MGD)	Total Flow (MGD)	Test Meter Flow (MGD)	Flow Diff (MGD)	% Diff Meter to Control Panel	Test Disch (psi)	Station Disch. (psi)	Diff (psi)	% Diff to Test to Station	Speed (rpm)	Tach. (rpm)	Diff (rpm)	% Diff to Tach. to Control Panel
1	3/15/00	3	50	15	64	42.0	-8.0	-16.0%	37.0	36.5	-0.50	-1%	500	472.9	27.1	5%
2	3/15/00	3	47	15	63	25.9	-21.1	-44.9%	34.5	34.0	-0.50	-1%	433	394.3	38.7	9%
3	3/15/00	3	14	10	25	9.0	-5.0	-35.7%	33.0	32.0	-1.00	-3%	362	332.2	29.8	8%
4	3/15/00	3	33	10	43	21.4	-11.6	-35.2%	34.0	33.0	-1.00	-3%	395	362.5	32.5	8%
5	3/15/00	3	50	17	70	35.3	-14.7	-29.4%	36.0	35.5	-0.50	-1%	475	434.7	40.3	8%
6	3/15/00	3	50	10	66	45.0	-5.0	-10.0%	38.0	37.0	-1.00	-3%	500	458.8	41.2	8%
7	3/15/00	3	18	10	31	11.0	-7.0	-38.9%	33.0	32.0	-1.00	-3%	370	343.6	26.4	7%
8	3/15/00	3	49	12	64	30.2	-18.8	-38.4%	34.5	34.0	-0.50	-1%	435	397.9	37.1	9%
9	3/15/00	3	29	16	43	19.6	-9.4	-32.4%	33.5	32.5	-1.00	-3%	395	361.3	33.7	9%
10	3/15/00	3	50	12	70	39.8	-10.2	-20.4%	36.0	35.5	-0.50	-1%	475	434.3	40.7	9%

Note: Columns in Italics are calculated and were not recorded in the field

Table 25: Matthews Park Pump Station Summary of Errors Between Pump Station Data and CATAD Data

Run #	Date	Time Panel	Time Pump Floor	Pump On CATAD	Pump #	Panel WW El.	CATAD WW el.	% Diff Control Panel to CATAD	Panel Total (mgd)	CATAD Flow (mgd)	% Diff Panel to CATAD	Portable Meter (mgd)	% Diff. Port. Meter to CATAD	Panel rpm	Tach. Rpm	CATAD rpm	% Diff Panel to CATAD	% Diff. Tach. to CATAD
Tests Run on December 9, 1999																		
1	12/9/99	11:24	11:24	9:59	1	93.5	94.56	1.12%	23.50	20.45	-14.91%	14.11	30.99%	710	706.0	765.0	7.19%	7.71%
2	12/9/99	11:36	11:36	11:36	1	95.4	95.17	-0.24%	24.00	20.89	-14.89%	14.40	31.07%	710	706.1	722.0	1.67%	2.21%
3	12/9/99	11:39	11:39	11:39	1	95.5	95.17	-0.35%	17.50	15.26	-14.68%	10.80	29.23%	670	661.2	717.7	6.65%	7.88%
4	12/9/99	11:43	11:43	11:43	1	95.9	95.60	-0.31%	10.00	7.33	-36.43%	5.54	24.37%	630	617.9	667.9	5.67%	7.48%
5	12/9/99	11:53	11:53	11:53	1	97.0	96.70	-0.31%	7.00	4.98	-40.56%	5.04	-1.20%	610	604.0	655.3	6.92%	7.83%
6	12/9/99	12:29	12:29	12:29	2	96.1	95.90	-0.21%	40.00	37.53	-6.58%	29.52	21.34%	600	592.7	681.6	11.97%	13.04%
7	12/9/99	12:34	12:34	12:34	2	94.9	94.63	-0.29%	38.00	36.32	-4.63%	24.48	32.60%	570	566.0	652.1	12.58%	13.20%
8	12/9/99	12:38	12:39	12:39	2	95.0	94.52	-0.51%	36.50	32.58	-12.03%	23.76	27.07%	550	547.0	628.3	12.46%	12.94%
9	12/9/99	12:42	12:42	12:42	2	95.4	95.01	-0.41%	31.00	29.34	-5.66%	21.60	26.38%	530	528.5	607.1	12.70%	12.95%
10	12/9/99	12:47	12:46	12:47	2	95.7	95.36	-0.36%	28.00	25.15	-11.33%	20.16	19.84%	510	513.0	596.9	14.56%	14.06%
Tests Run on March 15, 2000																		
6	3/15/00	10:49	10:49	10:49	3	92.6	92.39	-0.23%	50.00	44.81	-11.58%	45.00	-0.42%	500	458.8	378.9	-31.96%	-21.09%
7	3/15/00	10:57	10:57	10:58	3	93.2	95.06	1.96%	18.00	17.44	-3.21%	11.00	36.93%	370	343.6	272.8	-35.62%	-25.94%
8	3/15/00	11:03	11:04	11:04	3	93.5	92.85	-0.70%	49.00	47.39	-3.40%	30.20	36.27%	435	397.9	322.5	-34.89%	-23.38%
9	3/15/00	11:09	11:10	12:04	3	93.6	93.83	0.25%	29.00	25.2	-15.08%	19.60	22.22%	395	361.3	288.8	-36.78%	-25.11%
10	3/15/00	11:15	11:16	13:04	3	92.5	92.07	-0.47%	50.00	30.15	-65.84%	39.80	-32.01%	475	434.3	357.8	-32.76%	-21.38%

10.7 Matthews Park Pump Station – Data Analysis

The data collected during the pump runs was analyzed and corrected in order to develop pump curves. These pump curves were compared to manufacturer's pump curves and/or pump data provided by the County.

The pump data were corrected by using the pump affinity laws. These laws are used to convert flow and pressure data collected at a given pump speed to a set curve speed. This is done by multiplying the square of the ratio of curve speed to pump speed to correct for head, and multiplying the ratio of curve speed to pump speed to correct for flow.

The total differential head is calculated by adding the discharge head, velocity head, and suction head; and subtracting from this total the inlet head. The suction head for the pump station is calculated by adding the minor losses and friction losses of the inlet piping. This is calculated from each pump run based upon the measured flow.

Table 26 summarizes the data correction calculations and shows the corrected pump data. All pumps have been corrected to a pump speed based upon the factory curve speed. This is 705 rpm for Pump #1, 585 rpm for Pump #2, and 450 rpm for Pump #3. These speeds are within the optimal operating range for the respective pumps.

Figures 22 through 24 are plots of the corrected pump curves. Also shown on each figure is the factory curve generated from data provided by the pump manufacturer and/or the County's modeling database.

Table 26: Matthews Park Pump Station – Table of Corrected Pump Data

FIELD DATA						CORRECTED					CORRECTED			FLOW FROM
RUN NO.	PUMP NO.	BUBBLER LEVEL (ft)	TEST METER FLOW (gpm)	DISC. PRESS. (psi)	SPEED RPM	INLET HEAD	SUCTION HEAD	DISCH. HEAD (ft)	VELOCITY HEAD LOSS	TEST TOTAL HEAD	CURVE RPM	HEAD	FLOW	FACTORY CURVE
FIRST RUN. 12/9/99. PUMP #1 BETWEEN 11:24 AND 11:53														
1	1	93.5	9,800	34.00	706	7.7	1.0	78.5	1.7	73.6	705	**73.4**	**9786**	10600
2	1	95.4	10,000	34.00	706	9.6	1.1	78.5	1.8	71.8	705	**71.6**	**9984**	11050
3	1	95.5	7,500	34.00	661	9.7	0.6	78.5	1.0	70.5	705	**80.1**	**7997**	8750
4	1	95.9	3,850	34.00	618	10.1	0.2	78.5	0.3	68.9	705	**89.7**	**4393**	6500
5	1	97.0	3,500	34.00	604	11.2	0.1	78.5	0.2	67.7	705	**92.3**	**4085**	5800
SECOND RUN, 12/9/99, PUMP #2 BETWEEN 12:34 AND 12:47														
6	2	96.1	20,500	34.00	593	10.2	1.7	78.5	1.4	71.4	585	**69.6**	**20234**	22050
7	2	94.9	17,000	34.00	566	9.0	1.1	78.5	1.0	71.7	585	**76.6**	**17571**	20800
8	2	95.0	16,500	34.00	547	9.1	1.1	78.5	0.9	71.5	585	**81.7**	**17646**	19600
9	2	95.4	15,000	34.00	529	9.5	0.9	78.5	0.8	70.7	585	**86.6**	**16604**	18300
10	2	95.7	14,000	34.00	513	9.8	0.8	78.5	0.7	70.2	585	**91.3**	**15965**	16800
THIRD RUN, 3/15/00, PUMP #3 BETWEEN 10:49 AND 11:15														
6	3	92.6	31,250	38.00	459	5.0	1.92	87.8	1.6	86.3	450	**83.0**	**30650**	37200
7	3	93.2	7,639	33.00	344	5.6	0.12	76.2	0.1	70.9	450	**121.6**	**10004**	14400
8	3	93.5	20,972	34.50	398	5.9	0.87	79.7	0.7	75.4	450	**96.5**	**23718**	30000
9	3	93.6	13,611	33.50	361	6.0	0.37	77.4	0.3	72.1	450	**111.8**	**16953**	21000
10	3	92.5	27,639	36.00	434	4.9	1.51	83.2	1.2	81.0	450	**87.0**	**28638**	35200

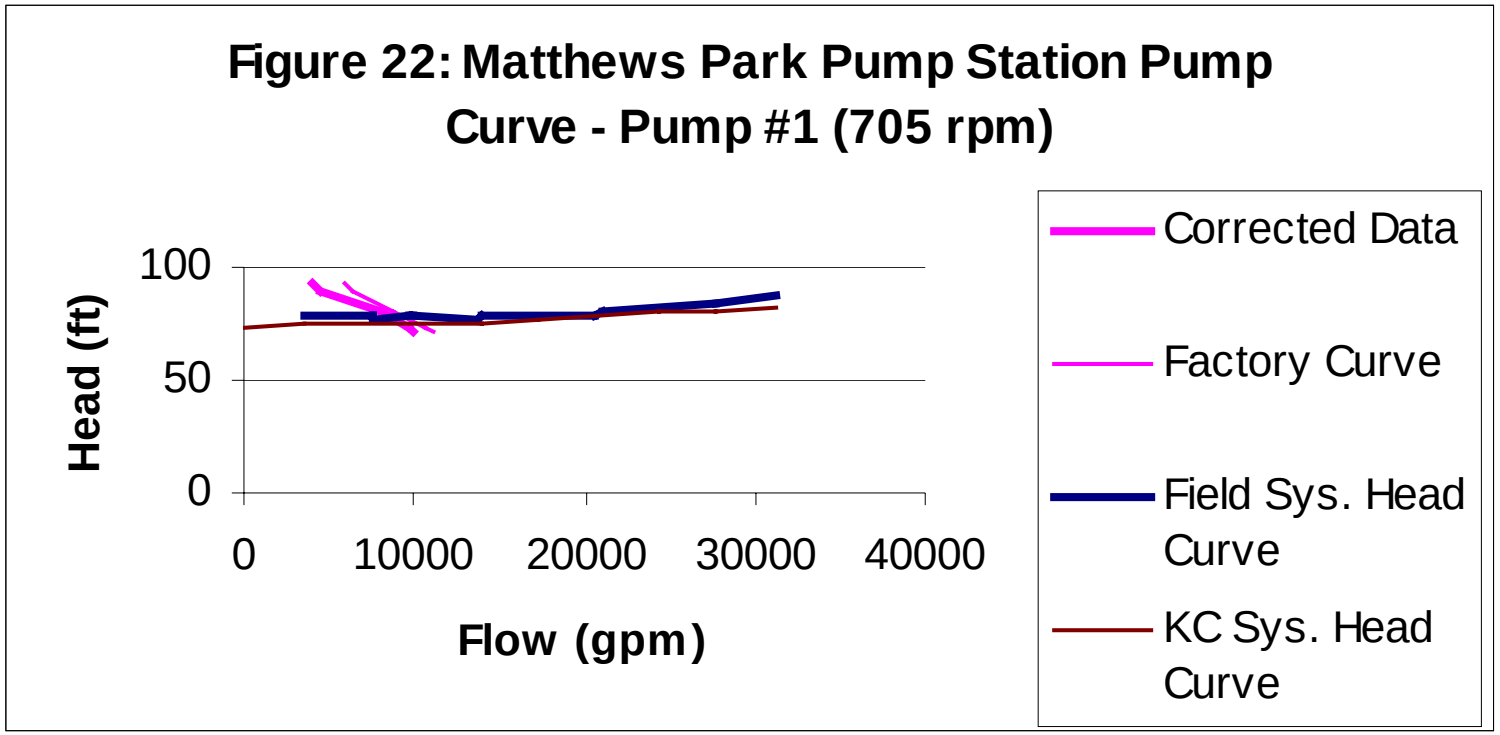
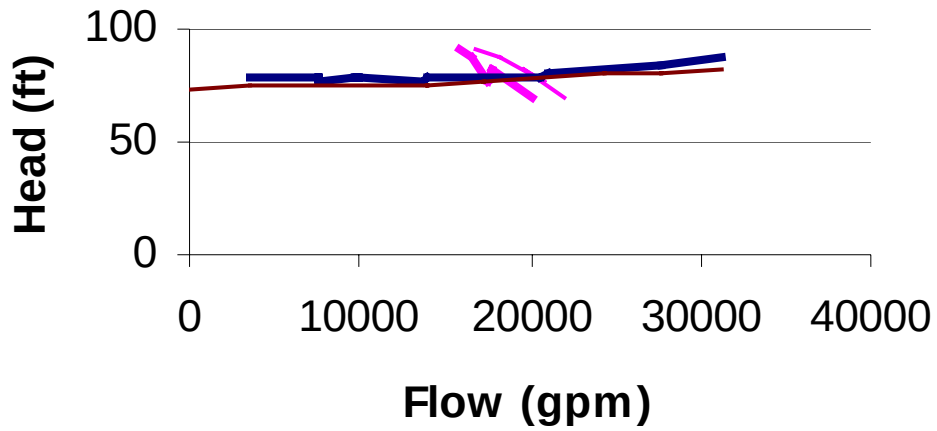


Figure 22: Matthews Park Pump Station Pump Curve - Pump #1 (705 rpm)
Head (ft)
100
50
0
0
10000
20000
30000
40000
Flow (gpm)
Corrected Data
Factory Curve
Field Sys. Head Curve
KC Sys. Head Curve

Figure 23: Matthews Park Pump Station Pump Curve - Pump #2 (585 rpm)



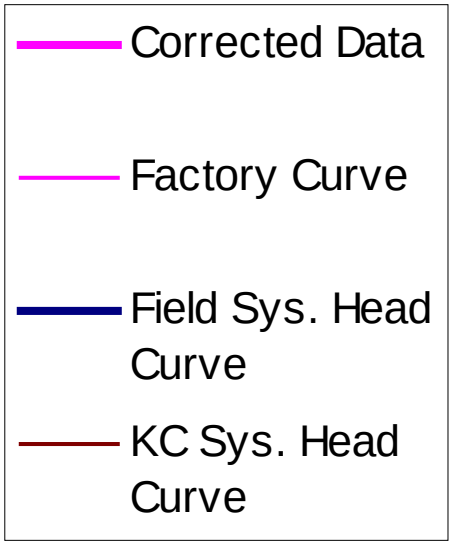
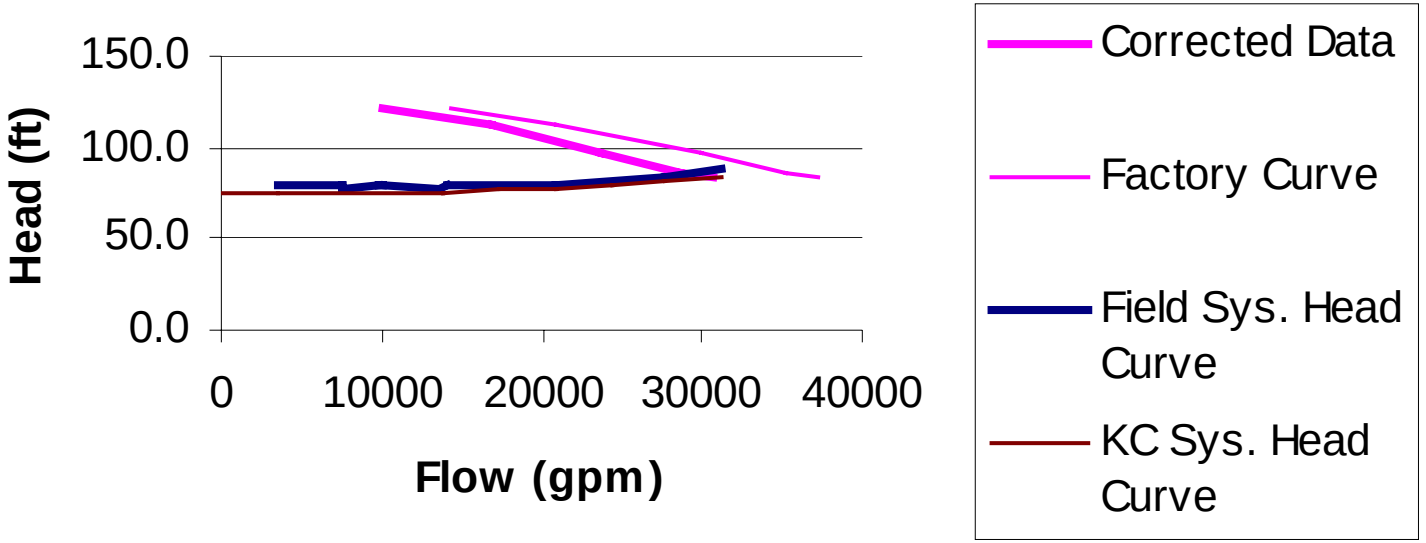


Figure 24: Matthews Park Pump Station Pump Curve - Pump #3 (450 rpm)



10.8 Matthews Park Pump Station – Observations & Recommendations:

Summarized below are the observations and recommendations for the flow, wet well elevation, and speed measurement. According to the scope of work, an error range within 10% is considered acceptable according to the Hydraulics Institute for Field Testing.

10.8.1 Flow Measurement:

Control Panel Flow vs. Portable Meter Flow:

- Pump #1 – There is not good correlation between the test data and the control panel data. The average error is approximately 38%. The station flow meter reads consistently above the test flow meter. The station flow meter should be checked and recalibrated.
- Pump #2 – There is not good correlation between the test data and the control panel data. The average error is approximately 31%. The station flow meter reads consistently above the test flow meter. The station flow meter should be checked and recalibrated.
- Pump #3 – There is not good correlation between the pump station flow meter and the test data. The average error is approximately 28%. The station flow meter reads consistently above the test flow meter. The station flow meter should be recalibrated.

Control Panel Flow vs. CATAD Flow Readings:

- Pump #1 – The data readings for the control panel flow and CATAD flow do not show good correlation. The average error between the control panel and CATAD flow data was approximately 24%. The control panel readings were consistently higher than the CATAD readings. The Pump #1 flow meter signal between the station control panel and the CATAD system should be checked and recalibrated.
- Pump #2 – There is reasonably good correlation between the Pump #2 station flow meter signal and the CATAD system. The control panel records higher flow values than the CATAD readings. The average error is approximately 8%. The County may wish to check this signal and recalibrate if necessary, but the margin of error is below the 10% criteria established for this study per the Hydraulics Institute for Field Testing.
- Pump #3 – There is some correlation between the Pump #3 station flow meter signal and the CATAD system. One data point showed considerably higher error than the other points taken in the tests. If this point is included, the average error is approximately 20%. If the point is omitted, the average error is approximately 8%. The control panel records higher flow values than the CATAD system. The County should check the signal and recalibrate if necessary.

10.8.2 Speed Measurement

Control Panel Tachometer vs. Hand-Held Tachometer:

- Pump #1 – There is good correlation between the Pump #1 control panel speed reading and the tachometer readings taken on the pump floor. The average error between the readings was approximately 1%. There is no need to recalibrate the Pump #1 speed meter on the Control Panel.
- Pump #2 – There is good correlation between the Pump #2 control panel speed readings and the tachometer readings taken on the pump floor. The average error between the control panel readings and the hand-held tachometer readings was approximately 1%. There is no need to recalibrate the Pump #2 speed meter on the Control Panel.
- Pump #3 – The control panel speed readings and the tachometer readings for Pump #3 show reasonably good correlation. The average error between the control panel readings and the hand-held tachometer readings was approximately 8%. Although this average error is below the 10% acceptable limit, the County may wish to check speed meter for Pump #3 and recalibrate it if necessary.

Control Panel RPM vs. CATAD RPM:

- Pump #1 – The data between the Pump #1 control panel speed and the CATAD system show good correlation. The average error between the readings is approximately 6%. Since the in-station tachometer is the data source for CATAD, they should agree closely. It is recommended the in-station speed meter be checked and recalibrated.
- Pump #2 – There is not good correlation between the Pump #2 control panel speed and the CATAD system reading. The average error between readings is approximately 15%. The signal between the Control Panel and the CATAD system for Pump #2 speed should be checked and recalibrated. The CATAD speed typically reads higher than the control panel speed.
- Pump #3 – There is not good correlation between the Pump #3 control panel speed and the CATAD system reading. The average error between readings is approximately 26%. The pump speed signal to the CATAD system for Pump #3 should be checked and recalibrated. The Control Panel speed typically reads higher than the CATAD speed.

10.8.3 Wet Well Elevation Measurement

Control Panel Wet Well Elevation vs. CATAD Wet Well Elevation:

- The control panel wet well elevation and the field measurement differed by 0.90 feet. (The panel measurement was less than the field measurement). The wet well bubbler should be checked and recalibrated.
- The plot of the control panel wet well elevation and the CATAD wet well readings show good correlation. The plot appears erratic but the percent error

between the control panel wet well elevations and the CATAD wet well elevations are less than 1%. The erratic plot is due to scale of the graph. There is no need to check or calibrate the signal between the control panel wet well meter and the CATAD data system.

10.8.4 Pump Curves

Pump #1:

- The corrected flow and head data from the test runs somewhat approximated the factory curve data. The pump is underperforming the pump curve data by approximately 18%.

Pump #2:

- The corrected data made an erratic plot but does appear to approximate the factory curve data. The field data may have been flawed due to unsteady flow, head, and speed readings during the pump test. The pump is underperforming the pump curve data by approximately 10%.

Pump #3:

- The corrected head and flow data from the test runs approximate the factory curve data. The corrected data underperform the factory curve data by approximately 10%.

SECTION 11 CARKEEK PARK PUMP STATION

11.1 Background

The Carkeek Pump Station is located within Carkeek Park in north Seattle. The pump station receives flow from the North Beach Pump Station and the local service area. The station pumps the flows into the 8th Avenue Interceptor where it continues on to the West Point Treatment Plant. During storm events and/or high flow events, excessive flows are directed to the Carkeek Storm Weather Treatment Plant for primary treatment, storage, and eventual return to the pump station. If the pump station storage is at capacity, the treated flows are disinfected and directed to the outfall into Puget Sound.

The fieldwork for this pump station was conducted entirely by King County staff and provided to the consultant team for the preparation of this report.

11.2 Pump Station Design Information

Key design information for the Carkeek Park Pump Station is summarized in the table below.

Carkeek Park Pump Station Elevation Information (Metro Datum)

Pump Room Floor	139.82 ft
Wet Well Grate	151.0 ft
Centerline Pump Suction	138.83 ft
Motor Room Floor	151.58 ft
Overflow Elevation	148.00 ft
Control Room Floor	151.58 ft

Carkeek Park Pump Station Pump and Motor Information

Pumping Units #1, #2, & #3:	
Pump:	
Model:	Fairbanks Morse Model 8-C5416X – Two Stage Configuration

Capacity:	4.2 mgd, 281 feet TDH, NPSHA 32.0 feet
Motor:	
Model:	*From offsite facilities manual:* Max. Speed 1,540 rpm; Max hp: 150 hp; type 2, energy efficient; mounted on the flywheel

11.3 Key Points and Issues

There were several key points and issues discovered during the testing and data analysis of the Carkeek Park Pump Station. They are summarized below:

- There are three pump sets, two each, working in stages. They are design to provide approximately 8 mgd pumping capacity and they are providing between 7 mgd and 7.5 mgd.
- The pump motors are controlled by VFD's. Each pump set runs off of one VFD.
- A calibration sticker was found for the wet well level sensor, JML 4/99. No other stickers were found.
- A vent was installed on Pump Set #1 between the first pump discharge and the second pump discharge.
- The portable meter was installed on the combined force main discharge upstream of the station's magnetic flow meter. This location was used to measure the flow for all tests on the three pumps.
- There may have been a discrepancy in the wet well calibration check. There was approximately 60 seconds between when the wet well elevation was read at the control panel and a measure-down taken in the wet well.

11.4 Measuring Equipment Setup at Carkeek Park Pump Station

On the pump floor, the in-station pressure gauges on the pump discharges were used to measure pressure (located at the discharge of the second pump in each set). There was no place to easily attach the portable pressure gauge. Since this is a reasonably new facility, the in-station gauges were assumed to be accurate.

The strap-on flow meter was positioned on the combined force main discharge. All flow reading for the three pump sets were taken from this transducer location. The flow meter transducers were set up for single-pass operation. Figure DIA – 8 in the Appendix is a schematic diagram of the piping and approximate equipment locations.

The hand-held tachometer was used on the section of the drive shaft above the pump. For each pump set, the speed was measured on each pump shaft with the hand-held tachometer.

Pressure gauge readings were taken from the installed pressure gauges on the pump discharges. Pressure gauge readings were read directly and hand recorded. The elevation from the centerline of the volute to the pump floor was taken from the record drawings to correct the pressure gauge reading. The discharge pressure readings taken at the pump discharge were used to calculate total dynamic head.

The wet well level was recorded for each pump run from the control panel. The wet well level bubbler was checked by measuring the distance to the water surface from the grate. When the elevation was calculated using the grate elevation from the record drawings, it differed by approximately 0.90 feet from the control panel reading.

No data logger was used.

11.5 Measuring Protocol at Carkeek Park Pump Station

11.5.1 Testing Sequence

The pumps were tested in a single day (January 18, 2000). Pump Set #3 was tested first at several speeds. This was done to get several points along the system head curve. Two test runs were conducted in tandem with Pump Set #1. Pump Set #1 was then tested at several speeds, one test conducted in tandem with Pump Set #3. Finally Pump Set #2 was tested at several speeds.

11.5.2 Measuring Protocol – Pump Floor

Data were read on the pump floor as follows:

- Flow: the pump flow was read directly from the Panametrics flow meter data display and hand recorded.
- Pressure: the discharge pressure from the pump was read directly from the in-station dial gauge at each pump discharge and hand recorded.
- Pump Speed: the pump speed was read from each of the drive shafts using the hand-held tachometer. One pump speed was reported since both shafts were being driven from the same VFD and had identical readings.
- Time: the time of the reading was taken from a wristwatch.

11.5.3 Measuring Protocol – Main Control Room

Data were read in the main control room as follows:

- Flow: in-station flow was read from two station flow meters, one located in the pump room and the other located in the control room. The station meter was a magnetic flow meter with a digital readout.
- Pressure: The force main pressure was read and recorded from the control panel.

- Wet Well Elevation: two wet well elevation measures were recorded. There are two gauges within the wet well that measure elevation. These were noted as Wet well El. A and Wet well El. B. They were installed for control redundancy (there is a lead/lag/compare strategy for control).
- Pump Speed: the pump speed was read directly from the station control panel.
- Time: the time was read from the control panel on the main floor.

11.6 Carkeek Park Pump Station: Collected Data

This section presents and compares the data collected at the Carkeek Park Pump Station. Data were collected on the pump floor using portable measuring devices and at the control panel. No reliable data was retrieved from the CATAD system.

Table 27 presents the hand-recorded data taken on January 18, 2000. Table 28 summarizes the differences between the hand-recorded data on the pump floor and the corresponding data recorded in the control room. This gives an indication of the error present between the control panel readings and the data readings from the portable measuring devices.

Figures A-76 through A-84 graph and compare the data collected at the pump floor and control panel. If the data matched exactly, it would plot along a 1:1 slope on the graph. These plots show how the data compare.

Table 27: Carkeek Park Pump Station Recorded Data

Run #	Date	Time (Main Floor)	Pump #	Wet Well Elev. A (ft)	Wet Well Elev. B (ft)	Station (rpm)	Sta Dnst (mgd)	Sta Upst (mgd)	Discharge Pressure Station (psi)	*Discharge Pressure Station (ft) (Calc)*	Test Meter (mgd)	*Test Flow (gpm)*	Pump Pressure (psi)	*Pump Pressure (ft) (Calc)*	Hand-Held Tach (rpm)	Notes
1	1/18/00	13:40	1 & 3	144.2	144.1	1190	3.59	3.55	108.2	*249.7*	3.48	*2,416.7*	109.0	*251.5*	1198.0	Didn't have stickers on 1 measure RPM yet
2	1/18/00	15:14	3	145.2	145.2	1309	3.29	3.3	107.9	*249.0*	3.25	*2,256.9*	108.5	*250.4*	1316.0	
3	1/18/00	15:22	3	144.9	144.8	1398	4.04	4.08	108.9	*251.3*	4.01	*2,784.7*	108.5	*250.4*	1401.5	
4	1/18/00	15:28	3	145.3	145.3	1201	2.08	2.08	106.8	*246.5*	2.04	*1,416.7*	107.8	*248.6*	1205.0	
5	1/18/00	15:32	3	146.9	146.9	1096	0.68	0.63	106	*244.6*	0.61	*423.6*	106.5	*245.8*	1100.0	went into draw & fill mode
6	1/18/00	15:38	1	145.6	142.0	1400	7.6	7.64	115.7	*267.0*	7.60	*5,277.7*	118.5	*273.4*	1403.5	check valve open 15:37, pumped ww down to
6	1/18/00	15:38	3	145.6	142.0	1398	7.60	7.64	115.7	*267.0*	7.60	*5,277.7*	116.0	*267.7*	1402.5	
7	1/18/00	15:49	1	146.4	146.4	1400	4.16	4.21	109	*251.572*	4.05	*2,812.5*	115.8	*267.1*	1403.5	check valve bouncing
8	1/18/00	15:52	1	NR	NR	NR	4.17	NR	NR	*NR*	4.05	*2,812.5*	115.8	*267.1*	1404.0	ww high float jammed, pumps ran full out 'til
9	1/18/00	16:08	1	145.8	145.9	1299	3.13	3.15	107.7	*248.6*	3.15	*2,187.5*	109.5	*252.7*	1303.0	portable flow +/-0.04, 3.19 start 3.11 end
10	1/18/00	16:11	1	146.2	146.3	1207	2.06	2.09	106.8	*246.5*	2.06	*1,430.6*	108.5	*250.4*	1210.0	varied +/-0.1 portable flow
																from 16:13 to 16:20 pump down wet well
11	1/18/00	16:24	1	146.8	146.8	1103	0.00	0.00	106	*244.6*	0.00	*0.0*	107.5	*248.1*	1106.0	shutoff
12	1/18/00	16:28	1	145.8	145.8	1400	7.59	7.61	115.8	*267.3*	7.39	*5,131.9*	117.5	*271.1*	1404.0	
12	1/18/00	16:28	3	145.8	145.8	1397	7.59	7.61	115.8	*267.3*	7.39	*5,131.9*	116.0	*267.7*	1402.0	
13	1/18/00	16:29	1	NR	NR	NR	7.55	NR	115.8	*267.3*	7.30	*5,069.4*	117.5	*271.1*	1404.0	
13	1/18/00	16:29	3	NR	NR	NR	7.55	NR	115.8	*267.3*	7.30	*5,069.4*	116.0	*267.7*	1403.0	
																next found pump 2 shutoff around 1120 rpm
14	1/18/00	16:36	2	146.5	146.6	1129	0.48	0.49	106.05	*244.8*	0.46	*316.0*	106.5	*245.8*	1132.0	oscillations
15	1/18/00	16:40	2	146.7	146.8	1440	4.16	4.18	109	*251.6*	3.85	*2,673.6*	110.3	*254.4*	1403.5	
16	1/18/00	16:44	2	146.7	146.8	1296	3.12	3.12	107.8	*248.8*	3.85	*2,673.6*	109.8	*253.3*	1300.0	
17	1/18/00	16:47	2	NR	NR	1209	NR	2.28	106.9	*246.7*	NR	*NR*	108.0	*249.2*	NR	controller took over, switch to fill&draw

Note: Columns in Italics are calculated and were not recorded in the field

NR – No Reading

Table 28: Carkeek Park Pump Station Summary of Errors Between Pump Floor and Control Room Data Readings

Run #	Date	Pump #	Control Panel Speed (rpm)	Tach. (rpm)	Speed Diff. (rpm)	%Diff. Tach. to Control Panel	*Disc. Press. Control Pnl (ft)*	*Pump Press Portable (ft)*	Diff. (ft)	% Diff. Port. to Control Panel	Station Flow Downstairs (mgd)	Station Flow Upstairs (mgd)	Diff. (mgd)	% Diff. Downstairs to Upstairs	Test Flow (mgd)	Diff. W/Upst. (mgd)	% Diff. Test Flow to Upstairs
1	1/18/00	1 & 3	1190	1198.0	-8.0	-0.7%	*249.7*	*251.6*	-1.8	-0.7%	3.59	3.55	-0.04	-1.1%	3.48	0.07	2.0%
2	1/18/00	3	1309	1316.0	-7.0	-0.5%	*249.0*	*250.4*	-1.4	-0.6%	3.29	3.3	0.01	0.3%	3.25	0.05	1.5%
3	1/18/00	3	1398	1401.5	-3.5	-0.3%	*251.3*	*250.4*	0.9	0.4%	4.04	4.08	0.04	1.0%	4.01	0.07	1.7%
4	1/18/00	3	1201	1205.0	-4.0	-0.3%	*246.5*	*248.7*	-2.2	-0.9%	2.08	2.08	0.00	0.0%	2.04	0.04	1.9%
5	1/18/00	3	1096	1100.0	-4.0	-0.4%	*244.6*	*245.8*	-1.2	-0.5%	0.68	0.63	-0.05	-7.9%	0.61	0.02	3.2%
6	1/18/00	1	1400	1403.5	-3.5	-0.3%	*267.0*	*273.5*	-6.5	-2.4%	7.6	7.64	0.04	0.5%	7.60	0.04	0.5%
6	1/18/00	3	1398	1402.5	-4.5	-0.3%	*267.0*	*267.7*	-0.7	-0.3%	7.6	7.64	0.04	0.5%	7.60	0.04	0.5%
7	1/18/00	1	1400	1403.5	-3.5	-0.3%	*251.6*	*267.1*	-15.6	-6.2%	4.16	4.21	0.05	1.2%	4.05	0.16	3.8%
8	1/18/00	1	NR	1404.0	n/a	n/a	*NR*	*267.1*	n/a	n/a	4.17	NR	n/a	n/a	4.05	n/a	n/a
9	1/18/00	1	1299	1303.0	-4.0	-0.3%	*248.6*	*252.7*	-4.2	-1.7%	3.13	3.15	0.02	0.6%	3.15	0.00	0.0%
10	1/18/00	1	1207	1210.0	-3.0	-0.2%	*246.5*	*250.4*	-3.9	-1.6%	2.06	2.09	0.03	1.4%	2.06	0.03	1.4%
11	1/18/00	1	1103	1106.0	-3.0	-0.3%	*244.6*	*248.1*	-3.5	-1.4%	0	0	0.00	n/a	0.00	0.00	n/a
12	1/18/00	1	1400	1404.0	-4.0	-0.3%	*267.3*	*271.2*	-3.9	-1.5%	7.59	7.61	0.02	0.3%	7.39	0.22	2.9%
12	1/18/00	3	1397	1402.0	-5.0	-0.4%	*267.3*	*267.7*	-0.5	-0.2%	7.59	7.61	0.02	0.3%	7.39	0.22	2.9%
13	1/18/00	1	NR	1404.0	n/a	n/a	*267.3*	*271.2*	-3.9	-1.5%	7.55	NR	n/a	n/a	7.30	n/a	n/a
13	1/18/00	3	NR	1403.0	n/a	n/a	*267.3*	*267.7*	-0.5	-0.2%	7.55	NR	n/a	n/a	7.30	n/a	n/a
14	1/18/00	2	1129	1132.0	-3.0	-0.3%	*244.8*	*245.8*	-1.0	-0.4%	0.475	0.49	0.02	3.1%	0.46	0.04	7.1%
15	1/18/00	2	1440	1403.5	36.5	2.5%	*251.6*	*254.5*	-2.9	-1.1%	4.16	4.18	0.02	0.5%	3.85	0.33	7.9%
16	1/18/00	2	1296	1300.0	-4.0	-0.3%	*248.8*	*253.3*	-4.5	-1.8%	3.115	3.12	0.00	0.2%	3.85	-0.73	-23.4%
17	1/18/00	2	1209	NR	n/a	n/a	*246.7*	*249.3*	-2.5	-1.0%	NR	2.28	n/a	n/a	NR	n/a	n/a

Note: Columns in Italics are calculated and were not recorded in the field

NR – No Reading

n/a – Not applicable

11.7 Carkeek Park Pump Station – Data Analysis

The data collected during the pump runs was analyzed and corrected in order to develop pump curves. These pump curves were compared to manufacturer's pump curves and/or pump data provided by the County.

The pump data were corrected by using the pump affinity laws. These laws are used to convert/correct flow and pressure data collected at a given pump speed to a set curve speed. This is done by multiplying the square of the ratio of curve speed to pump speed to correct for head, and multiplying the ratio of curve speed to pump speed to correct for flow.

The total differential head is calculated by adding the discharge head, velocity head, and suction head; and subtracting from this total the inlet head. The suction head for the pump station is calculated by adding the minor losses and friction losses of the inlet piping. This is calculated from each pump run based upon the measured flow.

Table 29 summarizes the data correction calculations and shows the corrected pump data. All pumps have been corrected to a pump speed of 1,450 rpm. This speed is within the optimal operating range for the pumps.

Figures 25 through 27 are plots of the corrected pump curves. Also shown on each figure is the factory curve generated from data provided by the pump manufacturer and/or the County's modeling database. Since each pump set is connected in series, the head values from the curves are added (multiplied by two since only one curve was provided) before being plotted with the corrected field data.

Table 29: Carkeek Park Pump Station – Table of Corrected Pump Data

FIELD DATA						CORRECTED DATA					CORRECTED			FLOW FROM
RUN NO.	PUMP NO.	BUBBLER LEVEL (ft)	TEST METER FLOW (gpm)	DISC. PRESS. (psi)	SPEED RPM	INLET HEAD	SUCTION HEAD	DISCH. HEAD (ft)	VELOCITY HEAD LOSS	TEST TOTAL HEAD	CURVE RPM	HEAD	FLOW	FACTORY CURVE
FIRST RUN. PUMP SET #3 BETWEEN 13:40 AND 15:32														
1	1 & 3	144.1	2,417	109.00	1198	1.3	2.8	251.8	4.8	258.1	1450	**378.2**	**2925**	1400
2	3	145.2	2,257	108.50	1316	2.4	2.5	250.6	4.2	254.9	1450	**309.5**	**2487**	2680
3	3	144.8	2,785	108.50	1402	2.0	3.8	250.6	6.4	258.8	1450	**277.0**	**2881**	3090
4	3	145.3	1,417	107.75	1205	2.5	1.0	248.9	1.6	249.1	1450	**360.6**	**1705**	1825
5	3	146.9	424	106.50	1100	4.1	0.1	246.0	0.1	242.2	1450	**420.8**	**558**	350
SECOND RUN, PUMP SET #1 & #3 BETWEEN 15:38 AND 16:28														
6	1	142.0	*2,493*	118.50	1404	-0.8	13.3	273.7	5.1	292.9	1450	**312.7**	**2575**	2375
6	3	142.0	5,278	116.00	1403	-0.8	13.3	268.0	22.8	304.9	1450	**325.9**	**5456**	2425
7	1	146.4	2,812	115.75	1404	3.6	3.83	267.4	6.5	274.1	1450	**292.6**	**2906**	2925
8	1	no reading	2,812	115.75	1404	N/a	3.8	267.4	6.5	N/a	1450	**N/a**	**2905**	
9	1	145.9	2,187	109.50	1303	3.1	2.3	252.9	3.9	256.1	1450	**317.2**	**2434**	2550
10	1	146.3	1,431	108.50	1210	3.5	1.0	250.6	1.7	249.9	1450	**358.8**	**1714**	1850
11	1	146.8	0	107.50	1106	4.0	12.6	248.3	0.0	256.9	1450	**441.6**	**0**	
12	1	145.8	5,132	117.50	1404	3.0	12.6	271.4	21.6	302.6	1450	**322.7**	**5300**	2480
12	3	145.8	5,132	116.00	1402	3.0	12.56	268.0	21.6	299.1	1450	**320.0**	**5308**	2515
13	1	no reading	5,069	117.50	1404	N/a	12.26	271.4	21.0	N/a	1450	**N/a**	**5236**	
13	3	no reading	5,069	116.00	1403	N/a	12.26	268.0	21.0	N/a	1450	**N/a**	**5239**	
THIRD RUN, PUMP SET #2 BETWEEN 16.36 AND 16:47														
14	2	146.6	316	106.50	1132	3.8	0.05	246.0	0.1	242.4	1450	**397.7**	**405**	900
15	2	146.8	2,674	110.25	1404	4.0	3.47	254.7	5.9	260.0	1450	**277.5**	**2762**	3080
16	2	146.8	2,674	109.75	1300	4.0	3.47	253.5	5.9	258.9	1450	**322.1**	**2982**	2480
17	2	no reading	no reading	108.00	no	N/a	N/a!	249.5	N/a	N/a	1450	**N/a**	**N/a**	

Figure 25: Carkeek Park Pump Station Pump Curve - Pump Set #1

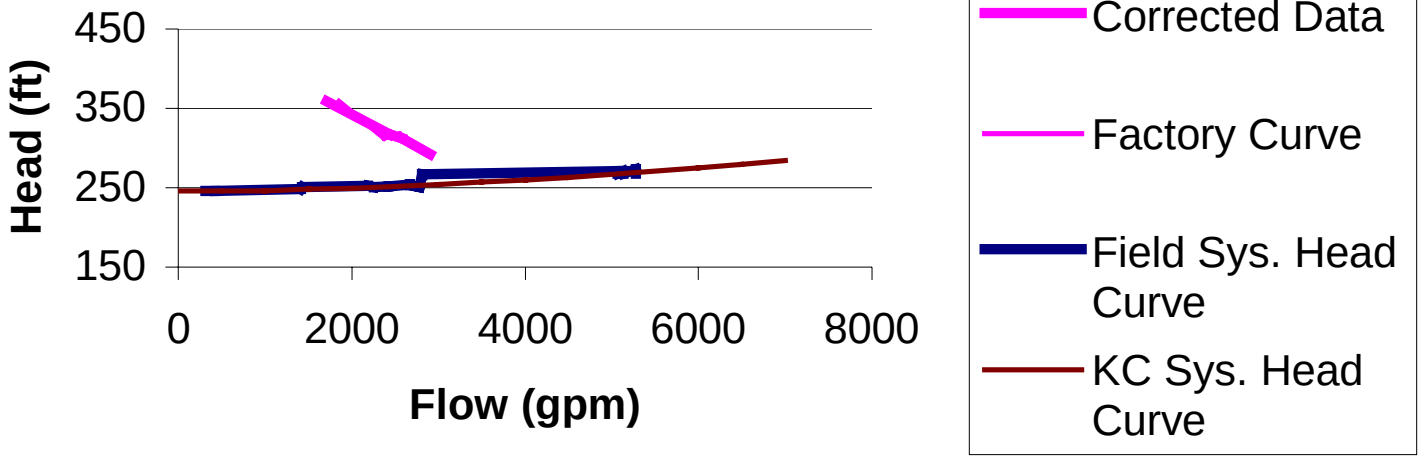


Figure 26: Carkeek Park Pump Station Pump Curve - Pump Set #2

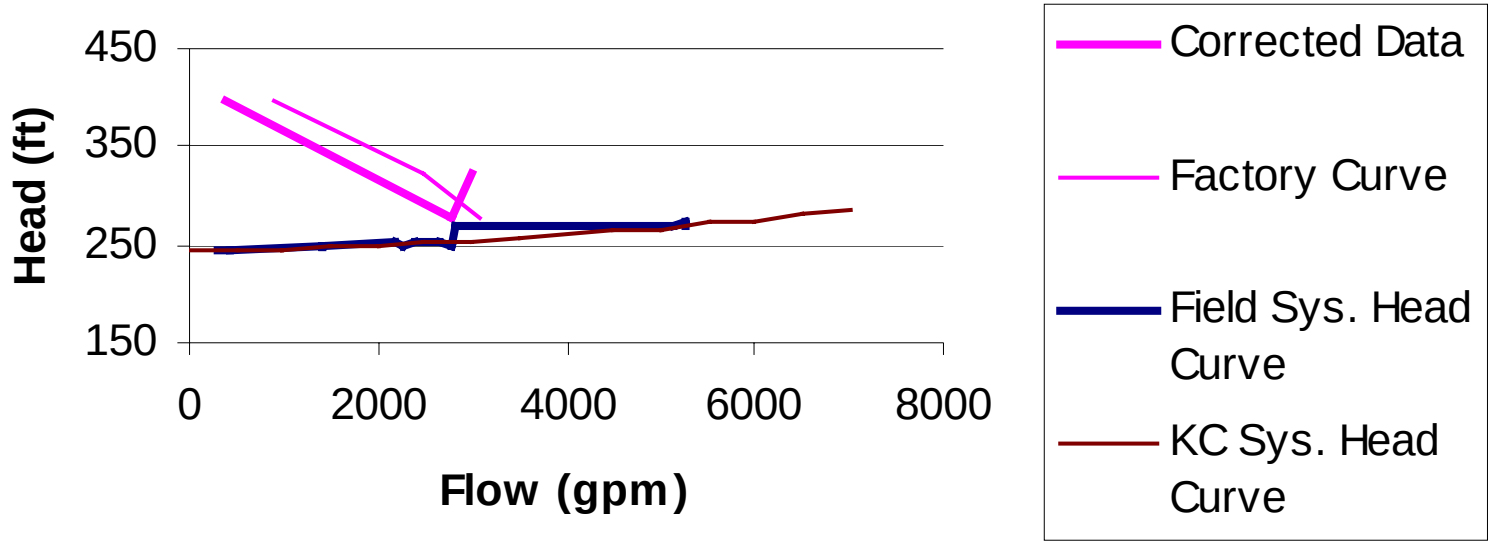
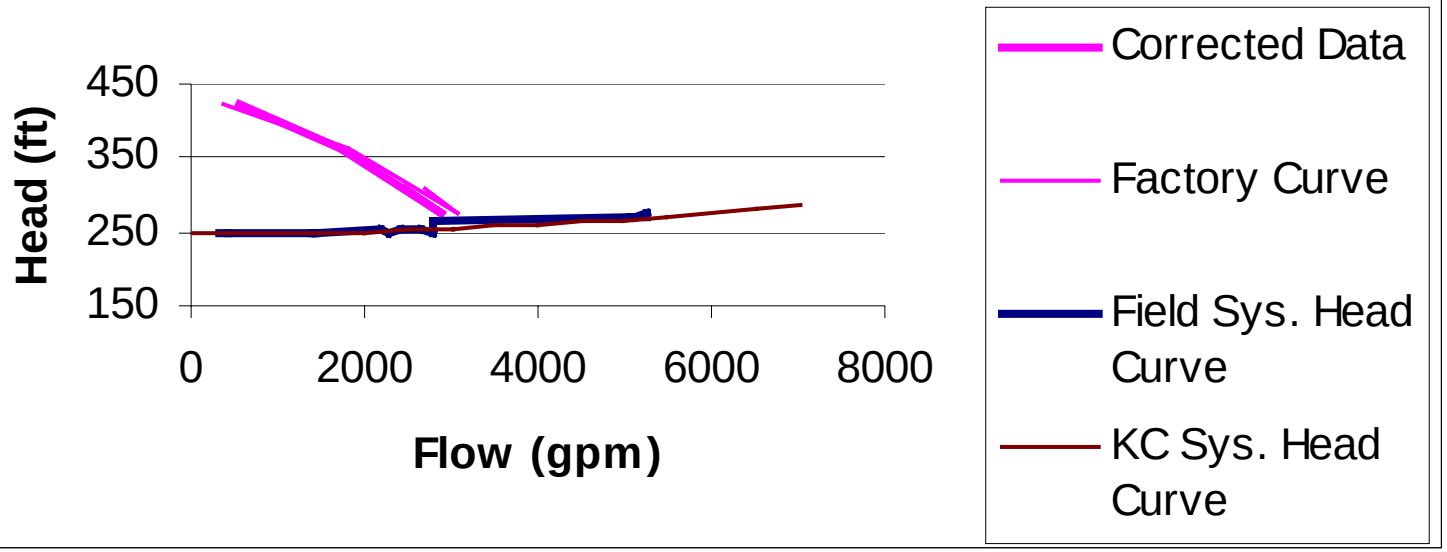


Figure 27: Carkeek Park Pump Station Pump Curve - Pump Set #3



11.8 Carkeek Park Pump Station – Observations & Recommendations:

Summarized below are the observations and recommendations for the flow, pressure, wet well elevation, and speed measurement. According to the scope of work, an error range within 10% is considered acceptable according to the Hydraulics Institute for Field Testing.

11.8.1 Flow Measurement:

Control Panel Flow:

- Pump Set #1 – The error between the flow readings on the pump station flow meter in the control room and in the pump room is less than 1%. There is no need to check or recalibrate these meters between themselves. The plot of the data for the portable flow meter and the upstairs flow meter shows good correlation. The error between the portable flow meter readings and the upstairs flow meter is less than 1%. There is no need to check or recalibrate the flow meters for Pump Set #1.
- Pump Set #2 – The error between the flow readings for the pump station flow meter in the control room and in the pump room is approximately 1%. There is no need to check or recalibrate these meters between themselves. The plot of the data for the portable flow meter and the upstairs flow meter shows reasonably good correlation. The error between the portable flow meter readings and the upstairs flow meter is approximately 3%. One reading was considerably off with an error of about 23%. This could have been a bad reading and not indicative of the accuracy of the control panel flow meter. The control panel flow meter for Pump Set #2 could be checked, but it probably does not need to be recalibrated.
- Pump Set #3 – The error between the flow readings for the pump station flow meter in the control room and in the pump room is approximately 1.5%. There is no need to check or recalibrate these meters between themselves. The plot of the data for the portable flow meter and the upstairs flow meter shows good correlation. The error between the portable flow meter readings and the upstairs flow meter is approximately 2%. There is no need to check or recalibrate the flow meters for Pump Set #3.

CATAD Flow Readings:

- There were no CATAD flow readings available from this testing. It is recommended that CATAD data be collected and compared with portable flow meter readings when the equipment and instrumentation at this pump station is checked and recalibrated.

11.8.2 Speed Measurement

Control Panel Tachometer vs. Hand-Held Tachometer:

- Pump Set #1 – There is good correlation between the control panel speed reading and the tachometer readings for the tests performed on Pump Set #1. The average error between the control panel speed measurements and the tachometer

measurements were less than 1%. The Pump Set #1 station speed meter does not need to be checked or recalibrated.

- Pump Set #2 – There is good correlation between the control panel speed reading and the tachometer readings for the tests performed on Pump Set #2. The average error between the readings was less than 1%. The Pump Set #2 station speed meter does not need to be recalibrated.
- Pumps Set #3 – There is good correlation between the control panel speed reading and the tachometer readings for the tests performed on Pump Set #3. The average error between the readings was less than 1%. The Pump Set #3 station speed meter does not need to be recalibrated.

CATAD RPM Readings:

- There were no CATAD rpm readings available from this testing. It is recommended that CATAD data be collected and compared after other equipment and instrumentation is checked and recalibrated.

11.8.3 Wet Well Elevation Measurement

Control Panel Wet Well Elevation vs. CATAD Wet Well Elevation:

- The control panel and field check of the wet well elevation differed by approximately 0.90 feet. The bubbler/level measuring equipment should be checked and recalibrated.
- There were no CATAD wet well data available for this testing. It is recommended that CATAD data be collected and compared when the pump station is recalibrated.

11.8.4 Pressure Measurement

Control Panel Pressure vs. Portable Pressure Gauge:

- Pump Set #1 – The pressure readings between the portable gauge and the control panel for the Pump #1 tests did not show good correlation when graphed. Several readings deviated and did not make a consistent plot. However, the average error between readings was low at approximately 2.3%. The pressure gauge readings were consistently higher than the control panel readings. It is recommended the control panel pressure gauge be checked and recalibrated only if it appears necessary.
- Pump Set #2 – The pressure readings between the portable gauge and the control panel for the Pump Set #2 tests showed reasonably good correlation. The average error between readings was approximately 1%. The control panel reading was consistently below the gauge pressure reading. There is no need to check or recalibrate the control panel pressure gauge.
- Pump Set #3 – The pressure readings between the portable gauge and the control panel for the Pump Set #3 tests showed reasonably good correlation. The average error between readings was less than 1%. All but one control panel reading was

less than the gauge pressure reading. There is no need to check or recalibrate the control panel pressure gauge.

11.8.5 Pump Curves

Pump Set #1:

- The corrected flow and head data from the Pump Set #1 test runs do show a good approximation of the factory pump curve. The corrected data runs through the factory curve and appear to giving the expected flow according to the factory curve for the same range of head values.

Pump Set #2:

- The corrected flow and head data from the Pump Set #2 test runs also show a approximation of the factory pump curve. The corrected test data does under-perform the corresponding factory curve values for the corresponding head values. The corrected field data indicate the pumps are under-performing the factory curves by an average of 15%. This could be because the factory curves we were given were for one set of pumps and not representative of all pumps in each pump set.

Pump Set #3:

- The corrected flow and head data from the Pump #3 test runs show a good approximation of the slope and shape of the factory curve data.

SECTION 12: INTERBAY PUMP STATION

12.1 Background

The Interbay Pump Station is located within the City of Seattle, west of Queen Anne Hill and east of Magnolia, adjacent to the Puget Sound. The pump station is located immediately south of the Magnolia Bridge. This pump station is part of the Elliot Bay interceptor system. The station receives flow from the Duwamish Pump Station and all of the regulator stations located on the interceptor. The station also receives flow from the South Magnolia Trunk. Wastewater is pumped through two 48-inch force mains and part of the Elliott Bay interceptor to the North Interceptor where it continues to flow to the West Point Treatment Plant.

12.2 Key Points and Issues

There were several key points and issues discovered during the site visit at the Interbay Pump Station on March 15, 2000. They are summarized below:

- There are three pumps manifolded into two force mains.
- Pump #2 is operated by an electric motor with an electric clutch. Pumps #1 and #3 are operated by natural gas powered engines.
- We were told that the station meter flow transducers are located outside the building on the force main, but not within an accessible vault.
- There is no location on the discharge piping within the pump room floor to locate the portable meter transducers. There is no adequate spacing between valves and fittings.
- The only straight runs of piping within the pump room piping have water cooling jackets for the natural gas engines.

12.3 Interbay Pump Station – Observations & Recommendations:

Summarized below are the observations and recommendations from the site visit.

- A portable flow meter cannot be attached to the piping at this station. Therefore no pump tests or measurements were conducted.
- The existing station flow meter should be located if possible.

- The County may wish to construct a vault along the force main route in order to install up to date flow meter transducers for the station meter and also to provide access for testing equipment.
- The County may want to try to measure flow at or near the force main discharge, which we were told was at the Wheeler Street Connection, in order to conduct testing, and measurement of the pump station. However, this may not be accurate enough to develop reliable conclusions and recommendations.

SECTION 13: SUMMARY OF RECOMMENDATIONS

This section presents a summary of recommendations for all eight pump stations which were tested. For a complete presentation of all the observations and recommendations, refer to the last subsection of each individual pump station section.

The table below presents the action items resulting from the findings and conclusions from the pump station testing and analysis.

Table 30

Summary of Observations & Action Items

Pump Station	Flow Measurement	Speed Measurement	Wet Well Elevation	Calibration Stickers
Kenmore	• Pump #1: Pump curves from test runs higher than King County Curve (Overperforming). • Pumps #2, #3, #4: Pump curves from test runs closely approximate King County Curves. • Pump #3 & #4: Check and recalibrate flow meter. Meter transducers may need to be replaced. • Pump #2 & #3: Check and recalibrate flow signal between control panel and CATAD system.	• Pump #2 & #3: Check and recalibrate speed signal between control panel and CATAD system.	• Bubbler checked within 0.03 feet (Panel reading higher than field measurement). • No need to recalibrate	None noted

Pump Station	Flow Measurement	Speed Measurement	Wet Well Elevation	Calibration Stickers
Woodinville	• Pump #1: Pump curves from test run lower than Factory Curve. (Underperforming). • Pumps #2 &#3: Pump curves from test runs higher than Factory Curves. (Overperforming). • Pump #1: Check and recalibrate flow meter. • Pump #1 & #2: Check the signal between control panel and CATAD system and recalibrate if necessary. There were some erratic data sets and the signal may need to be recalibrated.	• No Action Required.	• Bubbler checked within 0.85 feet (Panel reading higher than field measurement). • Check and recalibrate bubbler.	Station flow meters, 12-2-96 ("JB")

Pump Station	Flow Measurement	Speed Measurement	Wet Well Elevation	Calibration Stickers
Hollywood	• Pump #1: Pump Curve from test run approximate Factory Curve although it is steeper. • Pump #2: Pump Curve from test run erratic and does not appear to approximate the Factory Curve. • Pump #3: Pump curve from test run and Factory Curve correspond closely. • Pump #3: Check and recalibrate flow meter. • Pump #2 & #3: Check and recalibrate flow signal between control panel and CATAD system.	• No Action Required	• Bubbler checked within 0.18 feet (Panel reading lower than field measurement). • Check bubbler and recalibrate if necessary	No calibration stickers were found.

Pump Station	Flow Measurement	Speed Measurement	Wet Well Elevation	Calibration Stickers
York	• Pump #1: Pump Curve from test run is below Factory Curve. (Underperform). • Pump #3: Pump Curve from test run is below Factory Curve. (Underperform). • Pump #5: Pump Curve from test run does not correlate with Factory Curve. • Pump #1: Check flow signal between control panel and CATAD system. Recalibrate only if necessary.	• No Action Required	• The bubbler checked exactly with the control panel • No need to recalibrate.	No calibration stickers were found.
Hidden Lake	• Pump #1, #2, #3: Pump curves from test runs are below the Factory Curves. (Underperform). • The pump station flow meter is not operational. The flow meter should be repaired and recalibrated. • No CATAD data were available for these tests, check & verify CATAD flow signal.	• Pumps #1 & #2: Check and recalibrate the station speed meter. • No CATAD data were available for these tests, check & verify CATAD speed signal.	• The bubbler checked within 0.50 feet with the control panel (Control panel higher than field measurement). The bubbler should be checked and recalibrated. • No CATAD wetwell information available. Check & verify CATAD bubbler signal	No calibration stickers were found.

Pump Station	Flow Measurement	Speed Measurement	Wet Well Elevation	Calibration Stickers
North Beach	• Pump #1 & #2: Pump curves from test runs are erratic and do not appear to approximate the factory curves. • Pump #3 & #4: Pump curves from test runs approximate the slope and shape of the factory curves. The field curve for the pump plots erratically since they are constant speed pumps and fewer data points were measured. • There is no station flow meter. The County may wish to install a station flow meter in order to accurately measure flows from this station. • No CATAD data were available for these tests, check & verify CATAD flow signal.	• No CATAD data were available for these tests, check & verify CATAD speed signal.	• The bubbler checked within 0.20 feet with the control panel (Control Panel higher than field measurement). Check and recalibrate if necessary. • No CATAD wetwell information available. Check & verify CATAD bubbler signal.	No calibration stickers were found.

Pump Station	Flow Measurement	Speed Measurement	Wet Well Elevation	Calibration Stickers
Matthews Park	• Pumps #1, #2, and #3: Pump curves from test runs approximate slope and shape of factory curves. However, pump curves underperform factory curves. • Pumps #1, #2, & #3: Check and recalibrate flow meters. • Pumps #1, #2, & #3: Check and recalibrate the flow signals between the control panel and the CATAD system.	• Pump #3: Check and recalibrate the station speed meter. • Pump #1, #2 & #3: Check and recalibrate the speed signal between the control panel and the CATAD system.	• The bubbler checked within 0.90 feet with the control panel. (Control panel was lower than field measurement). The bubbler should be checked and recalibrated.	Station pressure transducer, 36" FM, JL, 8-19-99 Station discharge pressure gauges on all pumps, 5-31-94, JMI.
Carkeek Park	• Pump #1 & #3: Pump curves from field data show close correlation to factory curve data. • Pump #2: Pump curve from field data show same slope and shape as factory curve. However, the pump curve underperforms the factory curve. • No CATAD data were available for these tests, check & verify CATAD flow signal.	• No CATAD data were available for these tests, check & verify CATAD speed signal.	• The bubbler and control paneled differed by approximately 0.90 feet. Check and recalibrate. • No CATAD wetwell information available. Check & verify CATAD bubbler signal.	None noted.

APPENDIX

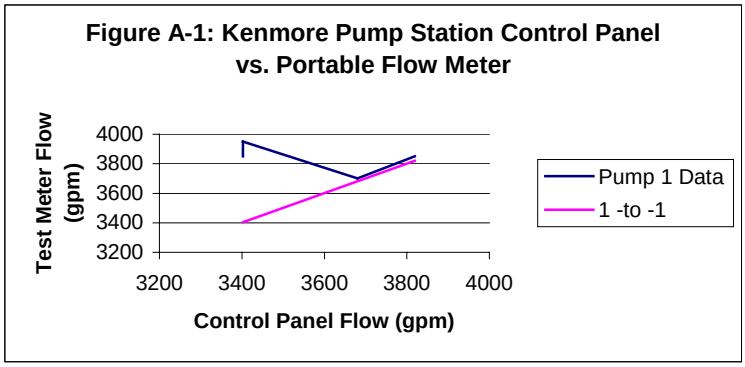


Figure A-1: Kenmore Pump Station Control Panel vs. Portable Flow Meter
Test Meter Flow (gpm)
4000
3800
3600
3400
3200
3200
3400
3600
3800
4000
Control Panel Flow (gpm)
Pump 1 Data
1 -to -1

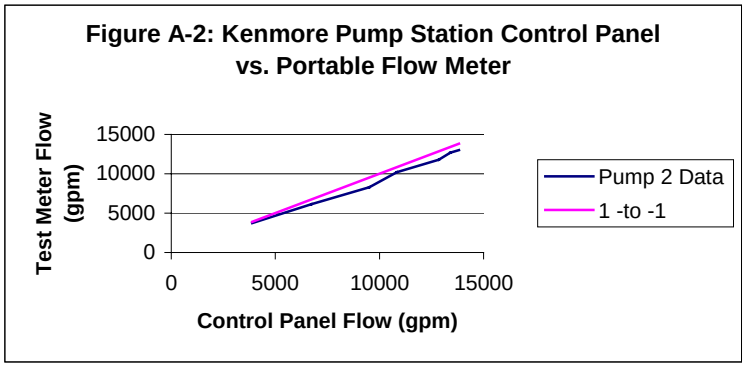


Figure A-2: Kenmore Pump Station Control Panel vs. Portable Flow Meter
Test Meter Flow (gpm)
15000
10000
5000
0
0
5000
10000
15000
Control Panel Flow (gpm)
Pump 2 Data
1 -to -1

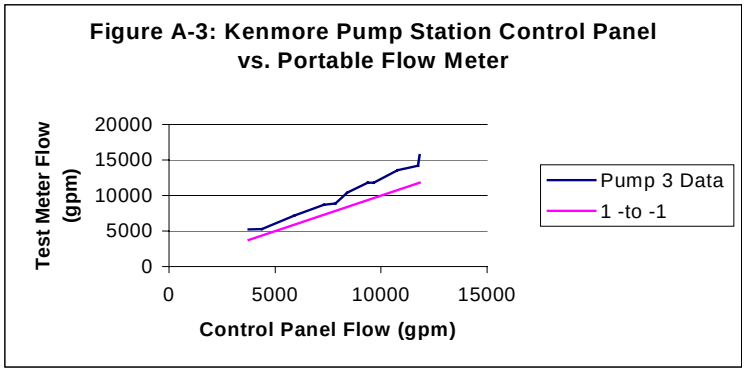


Figure A-3: Kenmore Pump Station Control Panel vs. Portable Flow Meter
Test Meter Flow (gpm)
20000
15000
10000
5000
0
0
5000
10000
15000
Control Panel Flow (gpm)
Pump 3 Data
1 -to -1

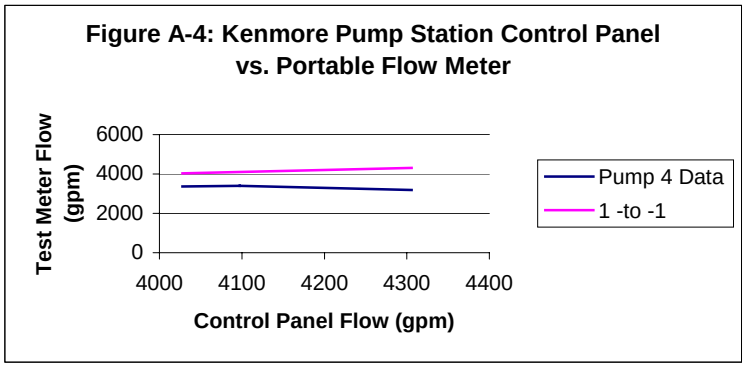


Figure A-4: Kenmore Pump Station Control Panel vs. Portable Flow Meter
Test Meter Flow (gpm)
6000
4000
2000
0
4000
4100
4200
4300
4400
Control Panel Flow (gpm)
Pump 4 Data
1 -to -1

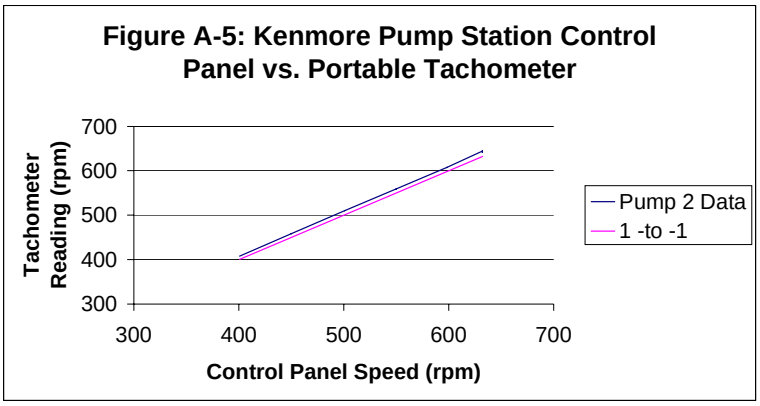


Figure A-5: Kenmore Pump Station Control Panel vs. Portable Tachometer
Tachometer Reading (rpm)
700
600
500
400
300
300
400
500
600
700
Control Panel Speed (rpm)
Pump 2 Data
1 -to -1

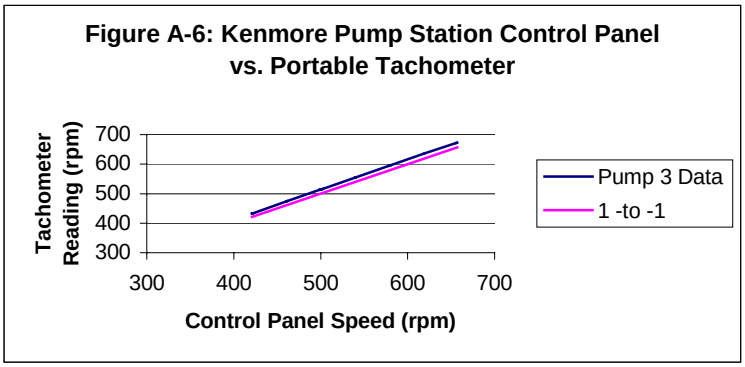


Figure A-6: Kenmore Pump Station Control Panel vs. Portable Tachometer
Tachometer Reading (rpm)
700
600
500
400
300
300
400
500
600
700
Control Panel Speed (rpm)
Pump 3 Data
1 -to -1

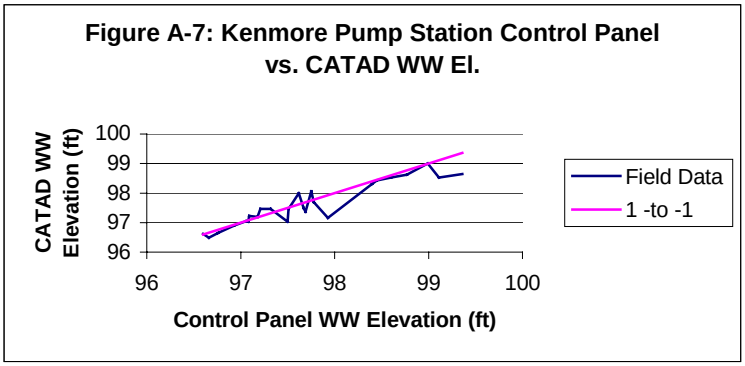


Figure A-7: Kenmore Pump Station Control Panel vs. CATAD WW El.
CATAD WW Elevation (ft)
100
99
98
97
96
96
97
98
99
100
Control Panel WW Elevation (ft)
Field Data
1 -to -1

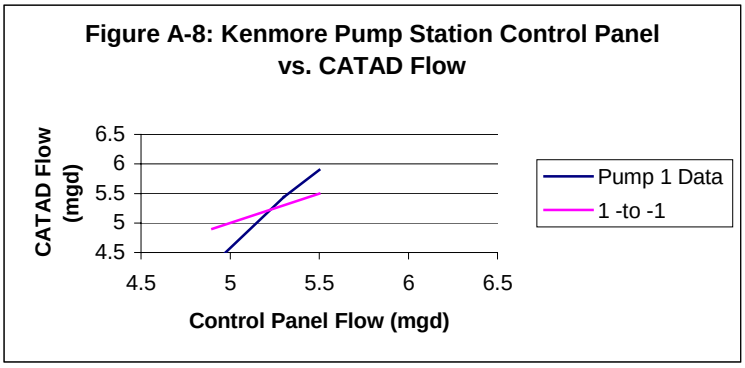


Figure A-8: Kenmore Pump Station Control Panel vs. CATAD Flow
CATAD Flow (mgd)
6.5
6
5.5
5
4.5
4.5
5
5.5
6
6.5
Control Panel Flow (mgd)
Pump 1 Data
1 -to -1

Figure A-9: Kenmore Pump Station Control Panel vs. CATAD Flow

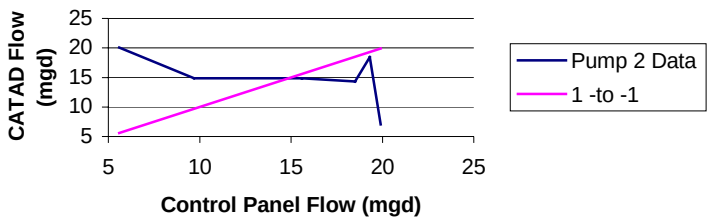


Figure A-10: Kenmore Pump Station Control Panel Flow vs. CATAD Flow

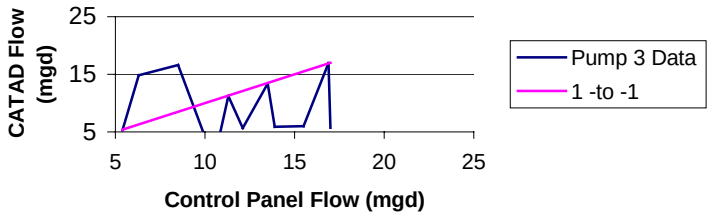


Figure A-11: Kenmore Pump Station Control Panel vs. CATAD Flow

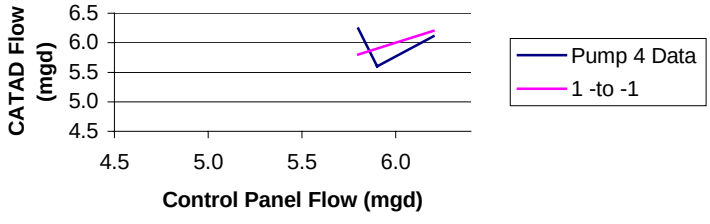
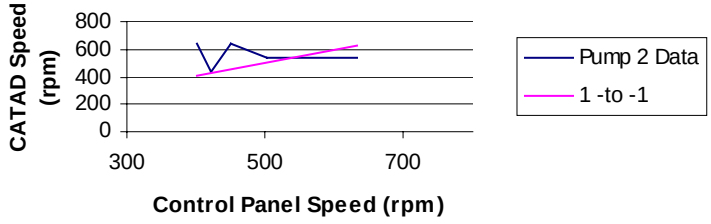


Figure A-12: Kenmore Pump Station Control Panel vs. CATAD RPM



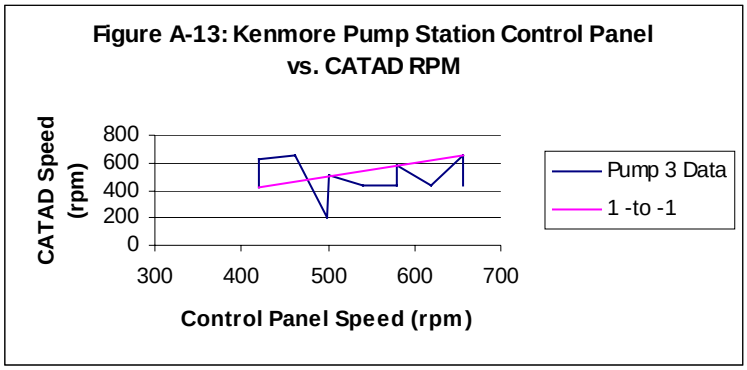


Figure A-13: Kenmore Pump Station Control Panel vs. CATAD RPM
CATAD Speed (rpm)
800
600
400
200
0
300
400
500
600
700
Control Panel Speed (rpm)
Pump 3 Data
1 -to -1

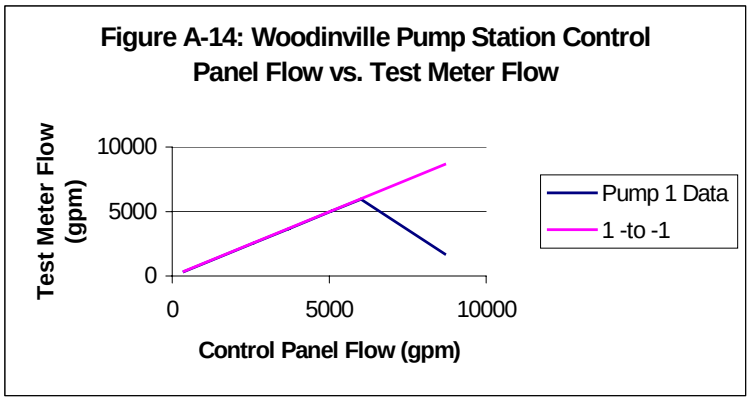


Figure A-14: Woodinville Pump Station Control Panel Flow vs. Test Meter Flow
Test Meter Flow (gpm)
10000
5000
0
0
5000
10000
Control Panel Flow (gpm)
Pump 1 Data
1 -to -1

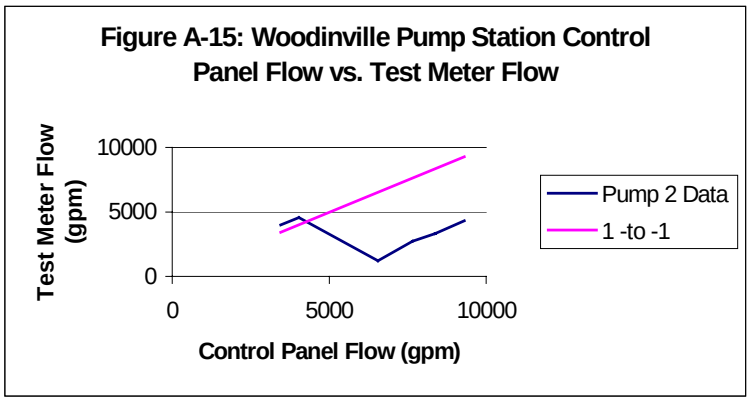


Figure A-15: Woodinville Pump Station Control Panel Flow vs. Test Meter Flow
Test Meter Flow (gpm)
10000
5000
0
0
5000
10000
Control Panel Flow (gpm)
Pump 2 Data
1 -to -1

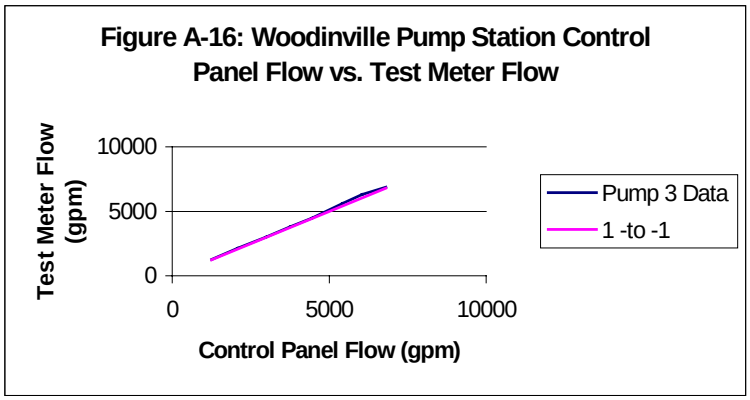


Figure A-16: Woodinville Pump Station Control Panel Flow vs. Test Meter Flow
Test Meter Flow (gpm)
10000
5000
0
0
5000
10000
Control Panel Flow (gpm)
Pump 3 Data
1 -to -1

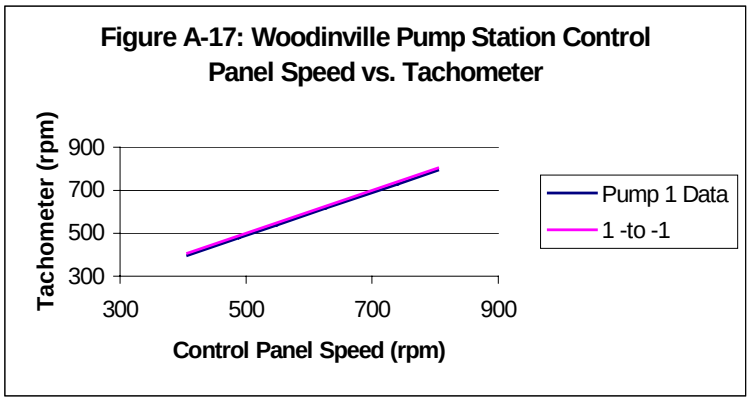


Figure A-17: Woodinville Pump Station Control Panel Speed vs. Tachometer
Tachometer (rpm)
900
700
500
300
300
500
700
900
Control Panel Speed (rpm)
Pump 1 Data
1 -to -1

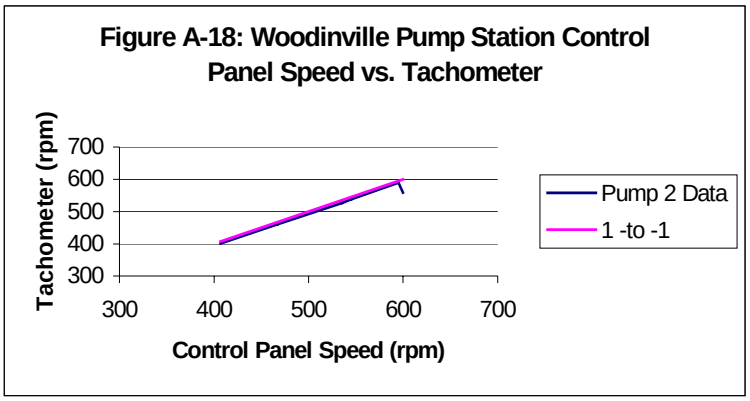


Figure A-18: Woodinville Pump Station Control Panel Speed vs. Tachometer
Tachometer (rpm)
700
600
500
400
300
300
400
500
600
700
Control Panel Speed (rpm)
Pump 2 Data
1 -to -1

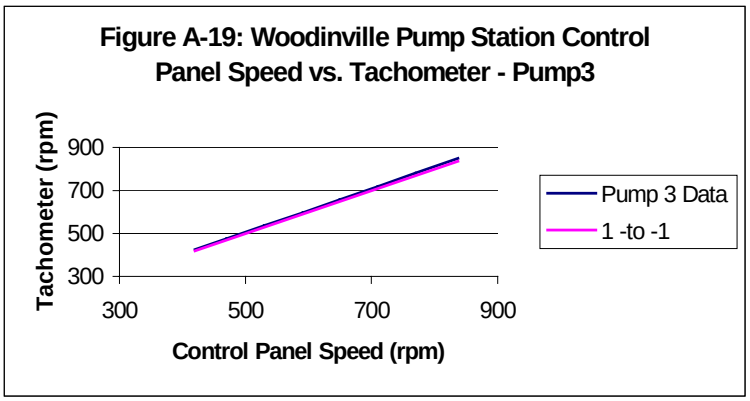


Figure A-19: Woodinville Pump Station Control Panel Speed vs. Tachometer - Pump3
Tachometer (rpm)
900
700
500
300
300
500
700
900
Control Panel Speed (rpm)
Pump 3 Data
1 -to -1

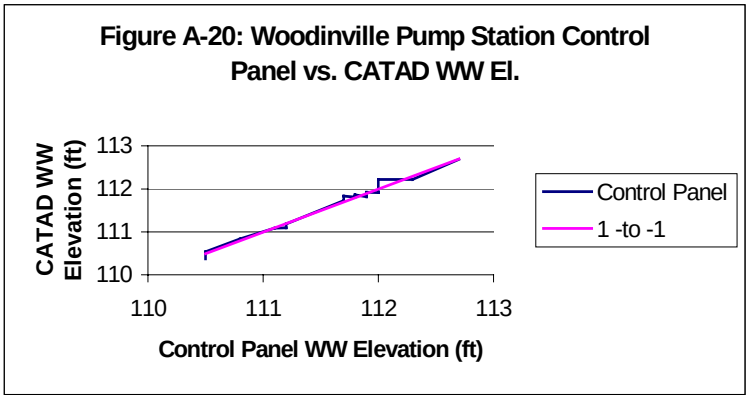


Figure A-20: Woodinville Pump Station Control Panel vs. CATAD WW El.
CATAD WW Elevation (ft)
113
112
111
110
110
111
112
113
Control Panel WW Elevation (ft)
Control Panel
1 -to -1

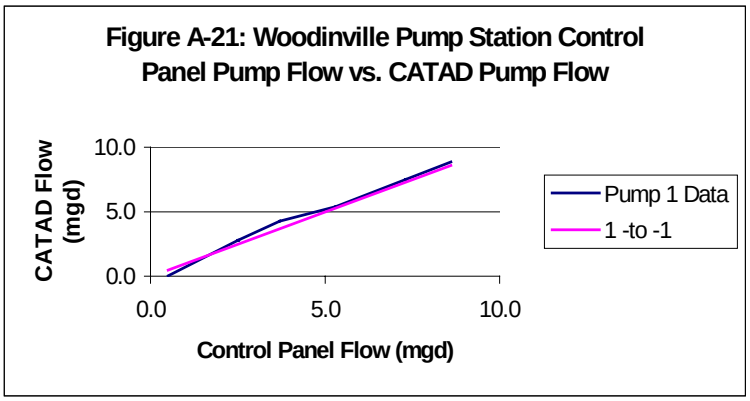


Figure A-21: Woodinville Pump Station Control Panel Pump Flow vs. CATAD Pump Flow
CATAD Flow (mgd)
10.0
5.0
0.0
0.0
5.0
10.0
Control Panel Flow (mgd)
Pump 1 Data
1 -to -1

Figure A-22: Woodinville Pump Station Control Panel Pump Flow vs. CATAD Pump Flow

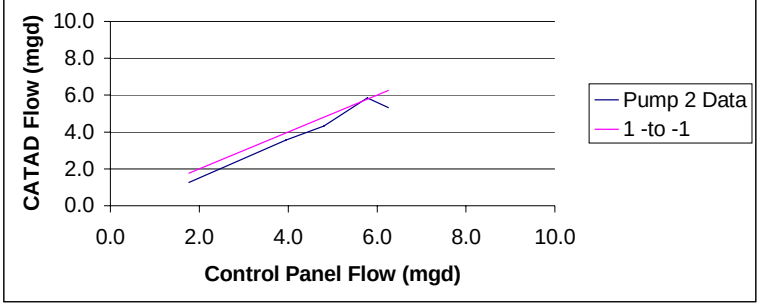


Figure A-23: Woodinville Pump Station Control Panel Pump Flow vs. CATAD Flow

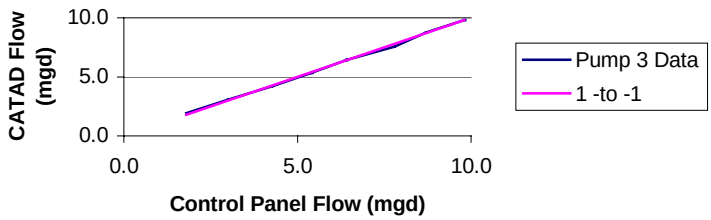


Figure A-24: Woodinville Pump Station Control Panel vs. CATAD RPM

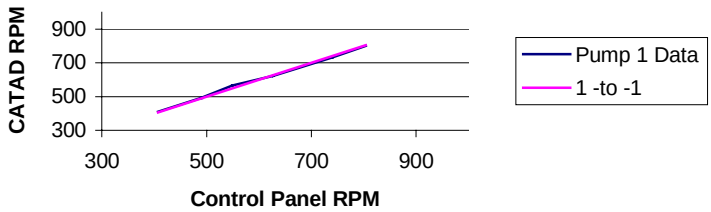
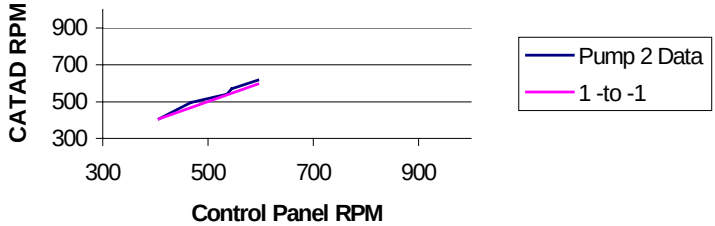


Figure A-25: Woodinville Pump Station Control Panel vs. CATAD RPM



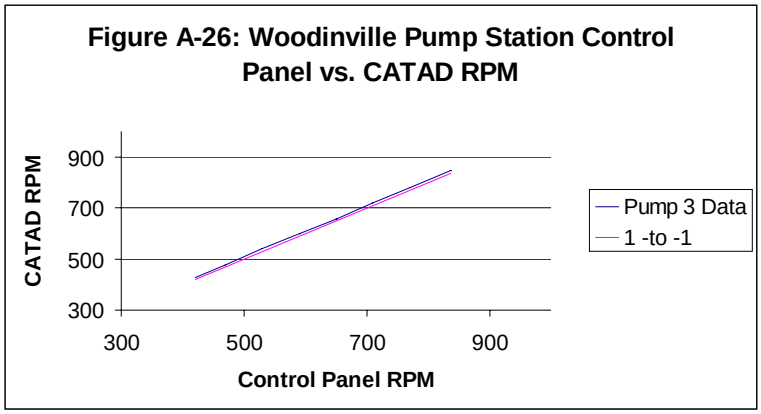


Figure A-26: Woodinville Pump Station Control Panel vs. CATAD RPM
CATAD RPM
900
700
500
300
300
500
700
900
Control Panel RPM
Pump 3 Data
1 -to -1

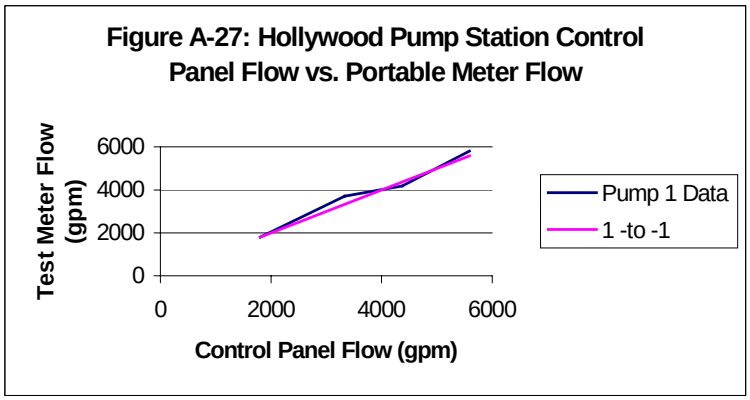


Figure A-27: Hollywood Pump Station Control Panel Flow vs. Portable Meter Flow
Test Meter Flow (gpm)
6000
4000
2000
0
0
2000
4000
6000
Control Panel Flow (gpm)
Pump 1 Data
1 -to -1

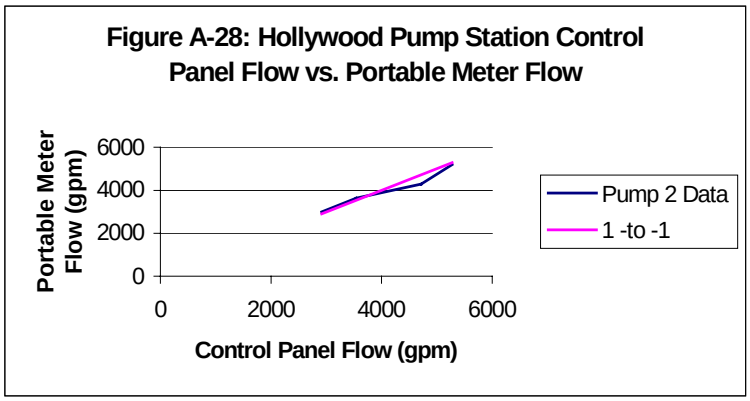


Figure A-28: Hollywood Pump Station Control Panel Flow vs. Portable Meter Flow
Portable Meter Flow (gpm)
6000
4000
2000
0
0
2000
4000
6000
Control Panel Flow (gpm)
Pump 2 Data
1 -to -1

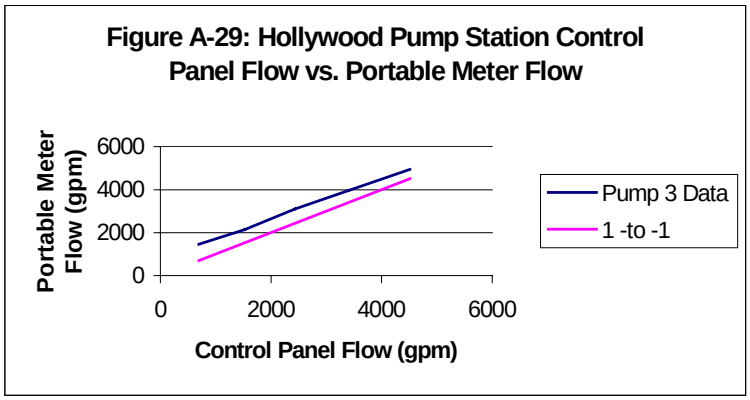


Figure A-29: Hollywood Pump Station Control Panel Flow vs. Portable Meter Flow
Portable Meter Flow (gpm)
6000
4000
2000
0
0
2000
4000
6000
Control Panel Flow (gpm)
Pump 3 Data
1 -to -1

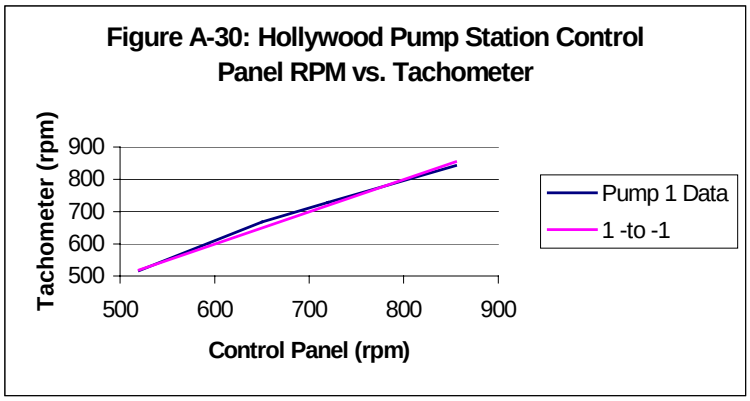


Figure A-30: Hollywood Pump Station Control Panel RPM vs. Tachometer
Tachometer (rpm)
900
800
700
600
500
500
600
700
800
900
Control Panel (rpm)
Pump 1 Data
1 -to -1

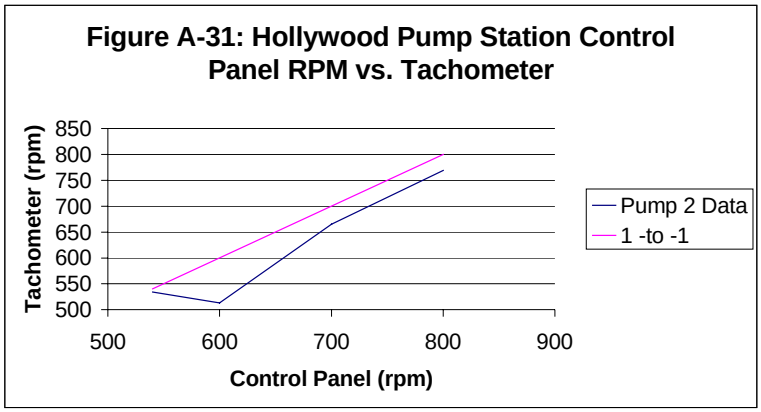


Figure A-31: Hollywood Pump Station Control Panel RPM vs. Tachometer
Tachometer (rpm)
850
800
750
700
650
600
550
500
500
600
700
800
900
Control Panel (rpm)
Pump 2 Data
1 -to -1

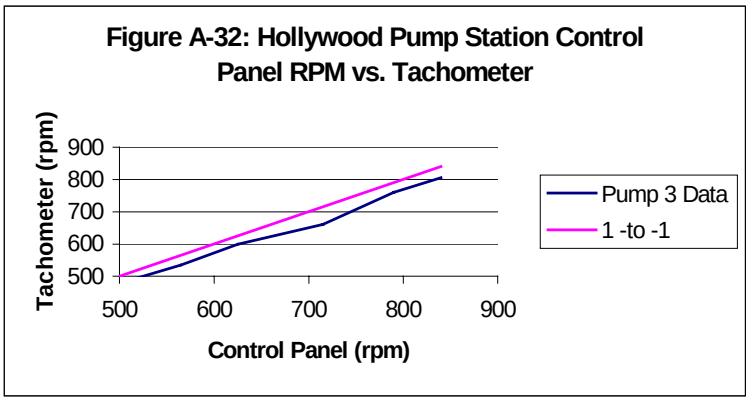


Figure A-32: Hollywood Pump Station Control Panel RPM vs. Tachometer
Tachometer (rpm)
900
800
700
600
500
500
600
700
800
900
Control Panel (rpm)
Pump 3 Data
1 -to -1

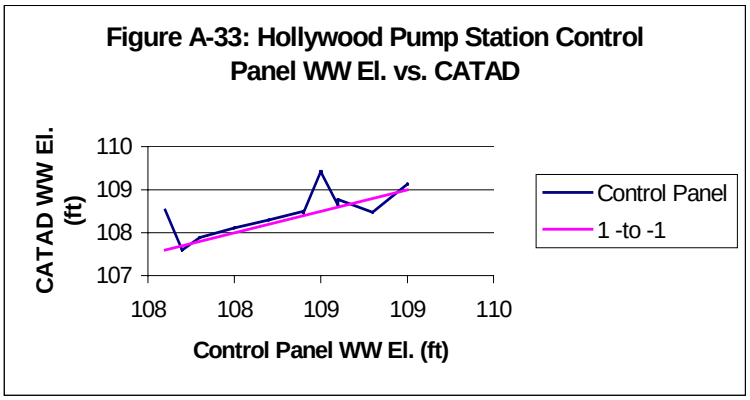


Figure A-33: Hollywood Pump Station Control Panel WW El. vs. CATAD
CATAD WW El. (ft)
110
109
108
107
108
108
109
109
110
Control Panel WW El. (ft)
Control Panel
1 -to -1

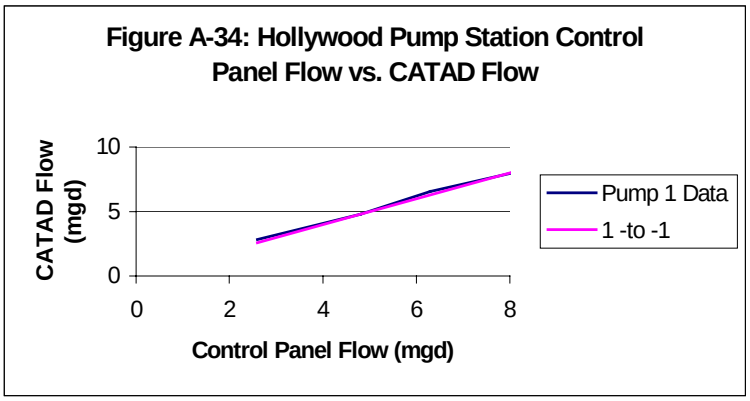


Figure A-34: Hollywood Pump Station Control Panel Flow vs. CATAD Flow
CATAD Flow (mgd)
10
5
0
0
2
4
6
8
Control Panel Flow (mgd)
Pump 1 Data
1 -to -1

Figure A-35: Hollywood Pump Station Control Panel Flow vs. CATAD

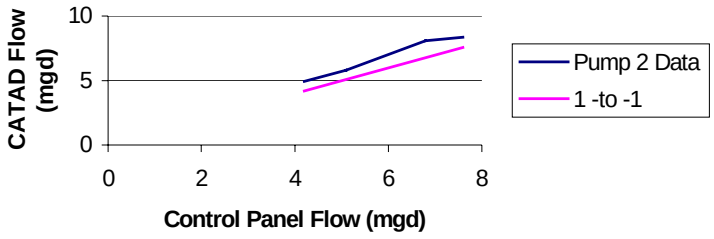


Figure A-36: Hollywood Pump Station Control Panel Flow vs. CATAD

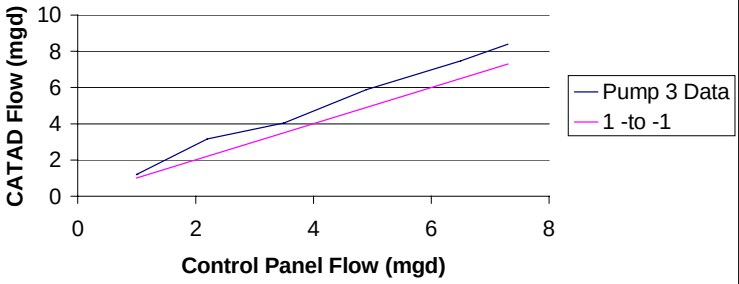
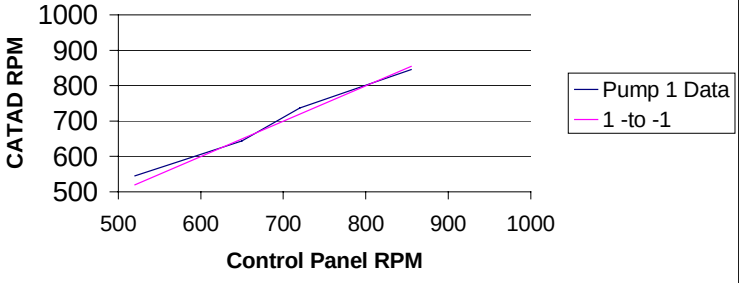
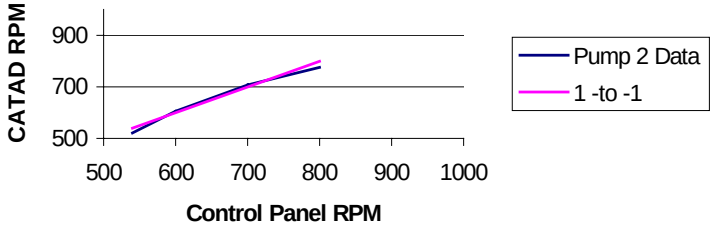


Figure A-37: Hollywood Pump Station Control Panel vs. CATAD RPM



FigureA-38: Hollywood Pump Station Control Panel vs. CATAD RPM



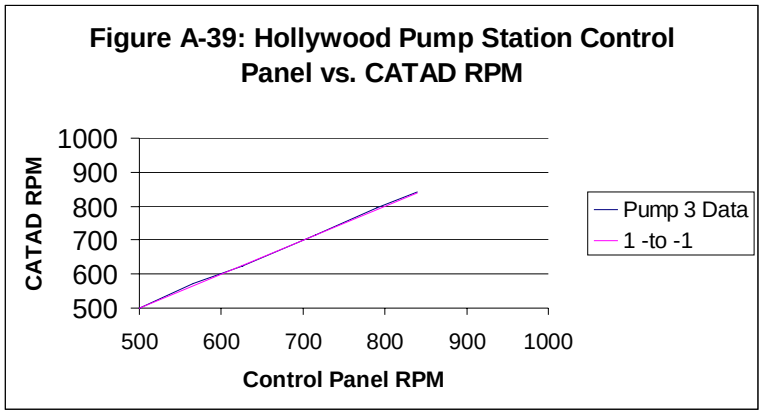


Figure A-39: Hollywood Pump Station Control Panel vs. CATAD RPM
CATAD RPM
1000
900
800
700
600
500
500
600
700
800
900
1000
Control Panel RPM
Pump 3 Data
1 -to -1

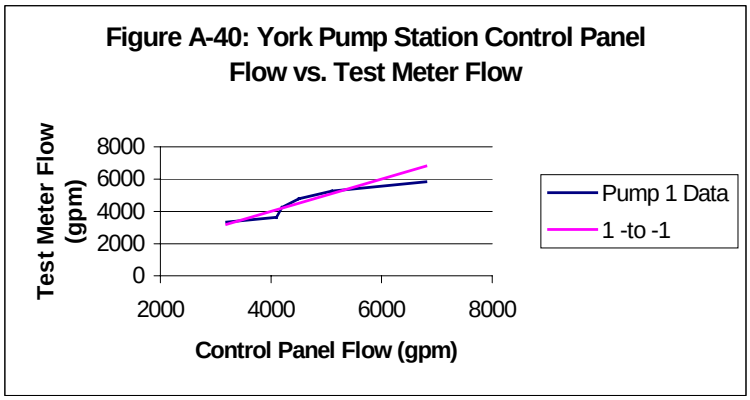


Figure A-40: York Pump Station Control Panel
Flow vs. Test Meter Flow
Test Meter Flow (gpm)
8000
6000
4000
2000
0
2000
4000
6000
8000
Control Panel Flow (gpm)
Pump 1 Data
1 -to -1

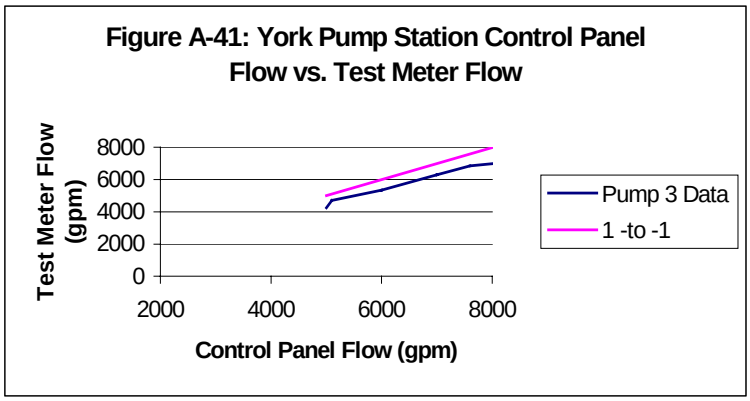


Figure A-41: York Pump Station Control Panel
Flow vs. Test Meter Flow
Test Meter Flow (gpm)
8000
6000
4000
2000
0
2000
4000
6000
8000
Control Panel Flow (gpm)
Pump 3 Data
1 -to -1

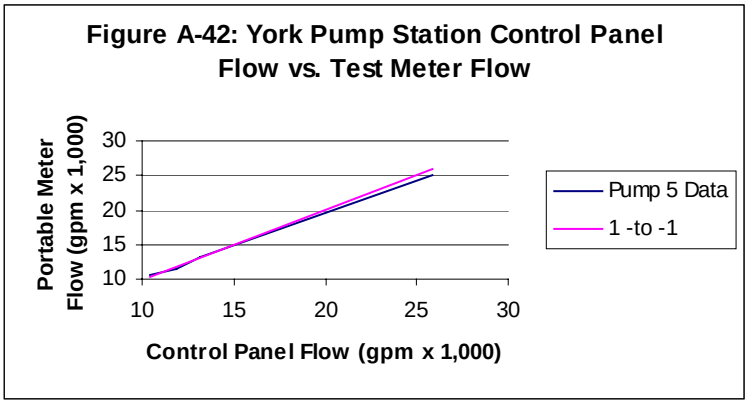


Figure A-42: York Pump Station Control Panel
Flow vs. Test Meter Flow
Portable Meter Flow (gpm x 1,000)
30
25
20
15
10
10
15
20
25
30
Control Panel Flow (gpm x 1,000)
Pump 5 Data
1 -to -1

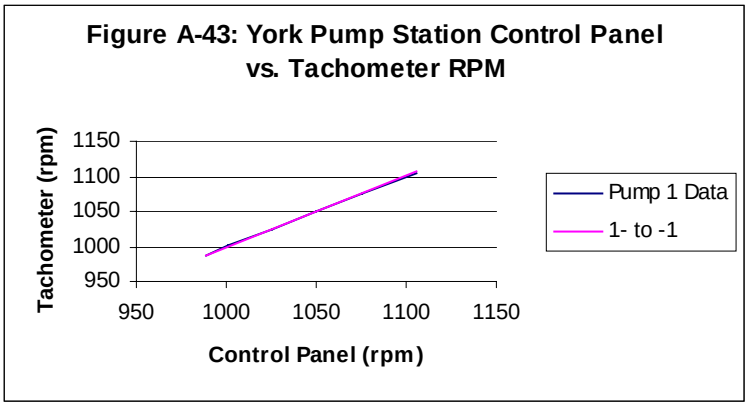


Figure A-43: York Pump Station Control Panel
vs. Tachometer RPM
Tachometer (rpm)
1150
1100
1050
1000
950
950
1000
1050
1100
1150
Control Panel (rpm)
Pump 1 Data
1- to -1

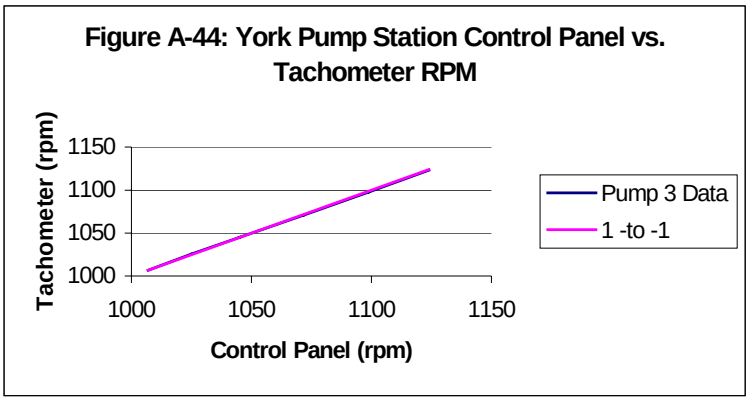


Figure A-44: York Pump Station Control Panel vs. Tachometer RPM
Tachometer (rpm)
1150
1100
1050
1000
1000
1050
1100
1150
Control Panel (rpm)
Pump 3 Data
1 -to -1

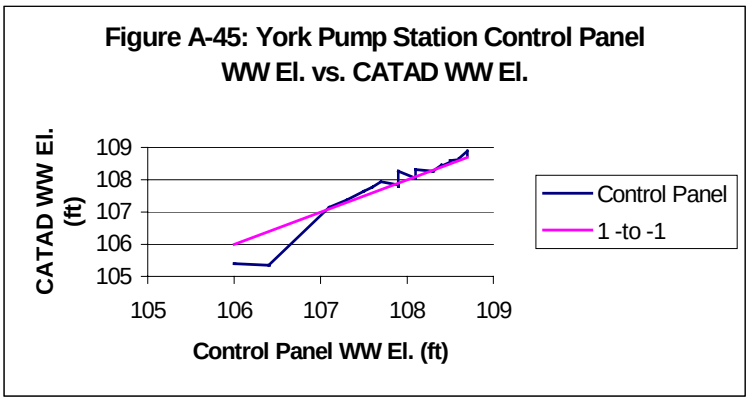


Figure A-45: York Pump Station Control Panel WW El. vs. CATAD WW El.
CATAD WW El. (ft)
109
108
107
106
105
105
106
107
108
109
Control Panel WW El. (ft)
Control Panel
1 -to -1

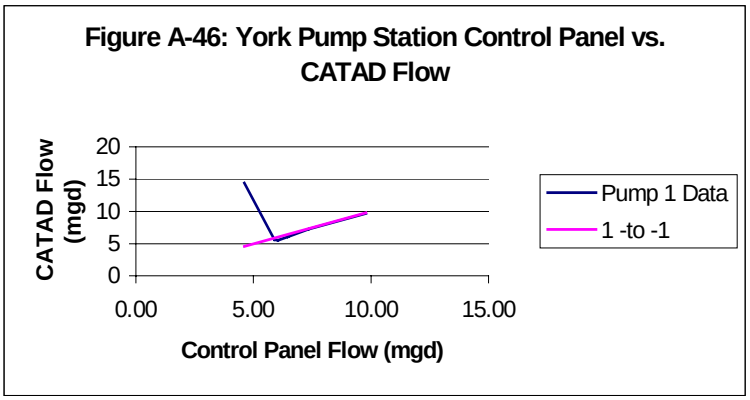


Figure A-46: York Pump Station Control Panel vs. CATAD Flow
CATAD Flow (mgd)
20
15
10
5
0
0.00
5.00
10.00
15.00
Control Panel Flow (mgd)
Pump 1 Data
1 -to -1

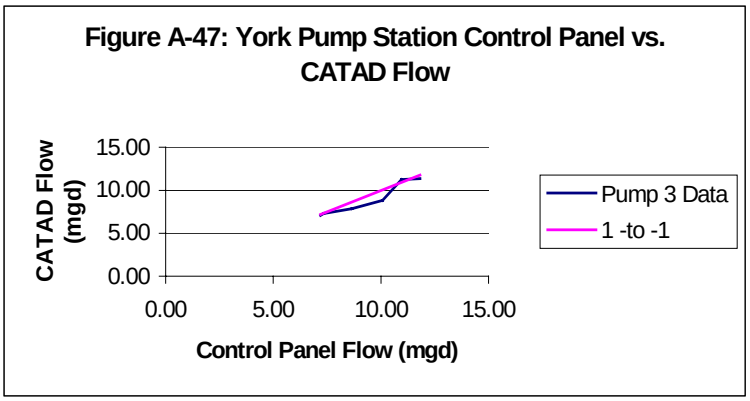


Figure A-47: York Pump Station Control Panel vs. CATAD Flow
CATAD Flow (mgd)
15.00
10.00
5.00
0.00
0.00
5.00
10.00
15.00
Control Panel Flow (mgd)
Pump 3 Data
1 -to -1

Figure A-48: York Pump Station Control Panel vs. CATAD Flow

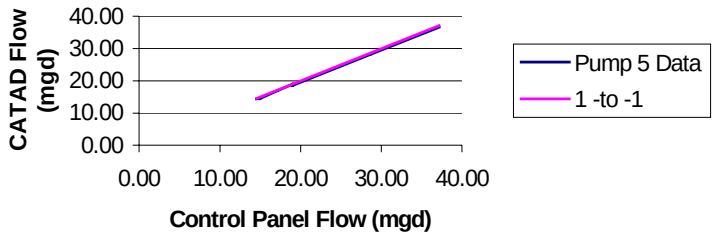


Figure A-49: York Pump Station Control Panel vs. CATAD RPM

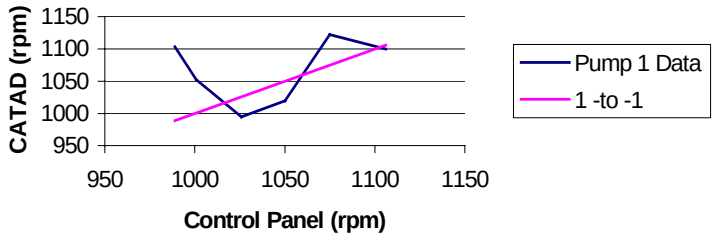
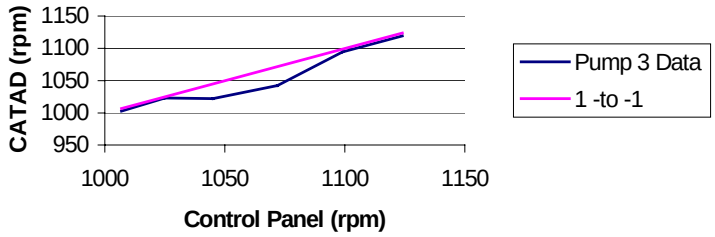


Figure A-50: York Pump Station Control Panel vs. CATAD RPM



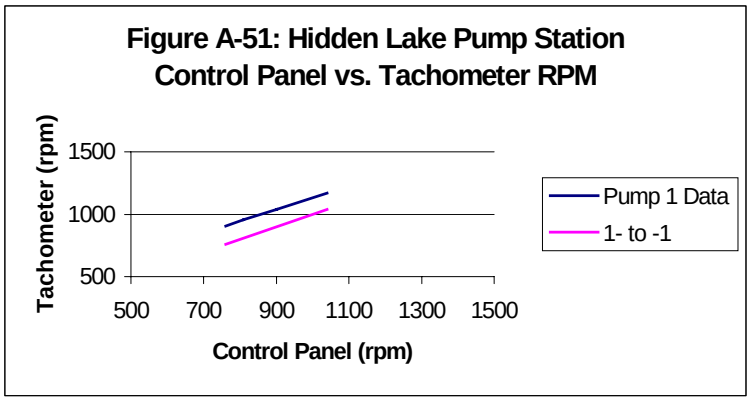


Figure A-51: Hidden Lake Pump Station Control Panel vs. Tachometer RPM
Tachometer (rpm)
1500
1000
500
500
700
900
1100
1300
1500
Control Panel (rpm)
Pump 1 Data
1- to -1

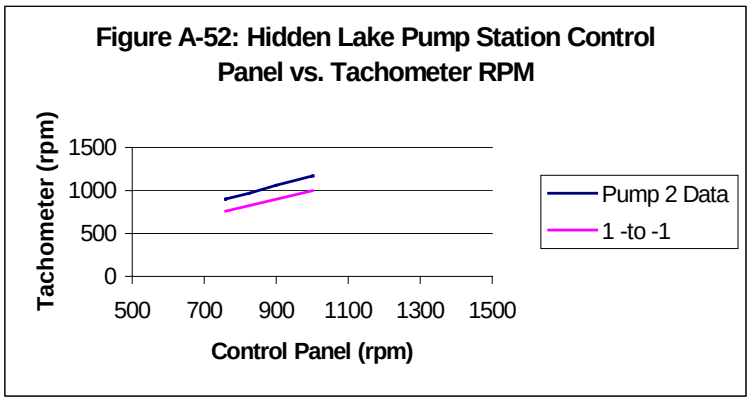


Figure A-52: Hidden Lake Pump Station Control Panel vs. Tachometer RPM
Tachometer (rpm)
1500
1000
500
0
500
700
900
1100
1300
1500
Control Panel (rpm)
Pump 2 Data
1 -to -1

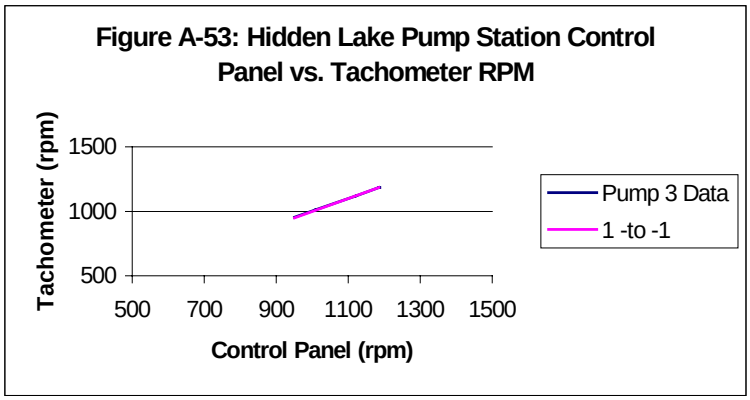


Figure A-53: Hidden Lake Pump Station Control Panel vs. Tachometer RPM
Tachometer (rpm)
1500
1000
500
500
700
900
1100
1300
1500
Control Panel (rpm)
Pump 3 Data
1 -to -1

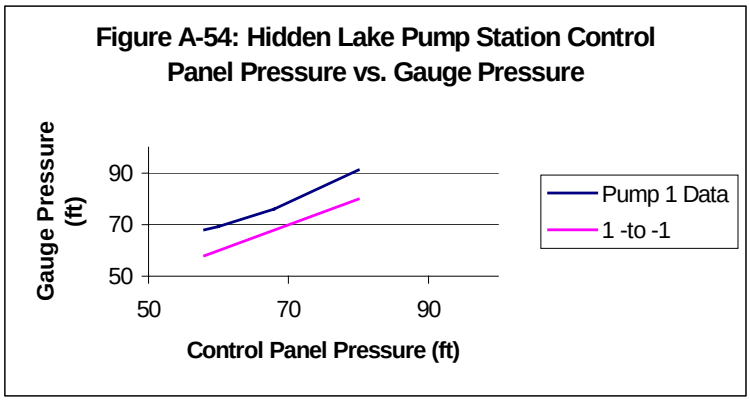


Figure A-54: Hidden Lake Pump Station Control Panel Pressure vs. Gauge Pressure
Gauge Pressure (ft)
90
70
50
50
70
90
Control Panel Pressure (ft)
Pump 1 Data
1 -to -1

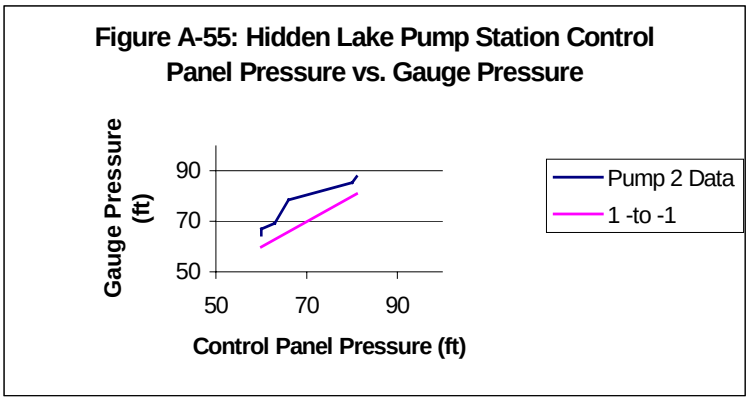


Figure A-55: Hidden Lake Pump Station Control Panel Pressure vs. Gauge Pressure
Gauge Pressure (ft)
90
70
50
50
70
90
Control Panel Pressure (ft)
Pump 2 Data
1 -to -1

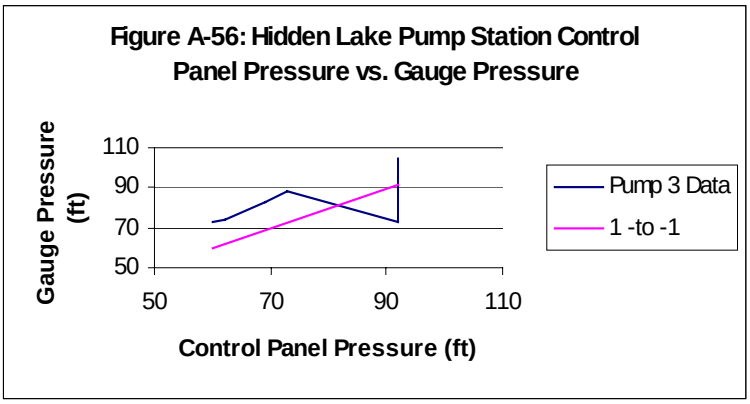


Figure A-56: Hidden Lake Pump Station Control Panel Pressure vs. Gauge Pressure
Gauge Pressure (ft)
110
90
70
50
50
70
90
110
Control Panel Pressure (ft)
Pump 3 Data
1 -to -1

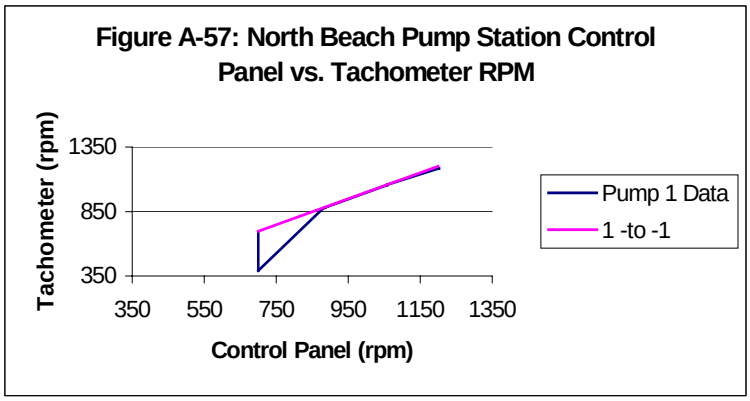


Figure A-57: North Beach Pump Station Control Panel vs. Tachometer RPM
Tachometer (rpm)
1350
850
350
350
550
750
950
1150
1350
Control Panel (rpm)
Pump 1 Data
1 -to -1

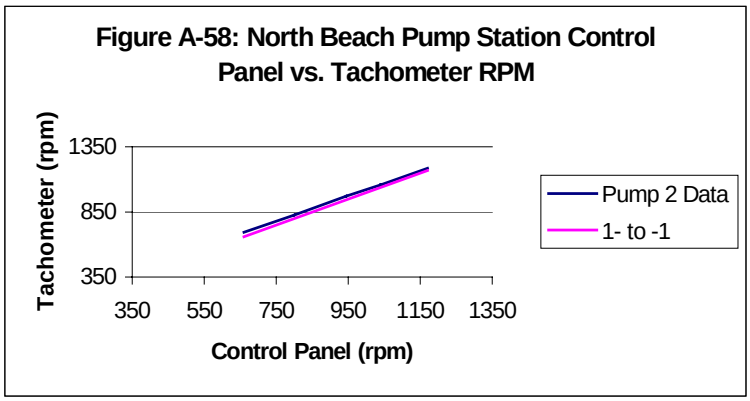


Figure A-58: North Beach Pump Station Control Panel vs. Tachometer RPM
Tachometer (rpm)
1350
850
350
350
550
750
950
1150
1350
Control Panel (rpm)
Pump 2 Data
1- to -1

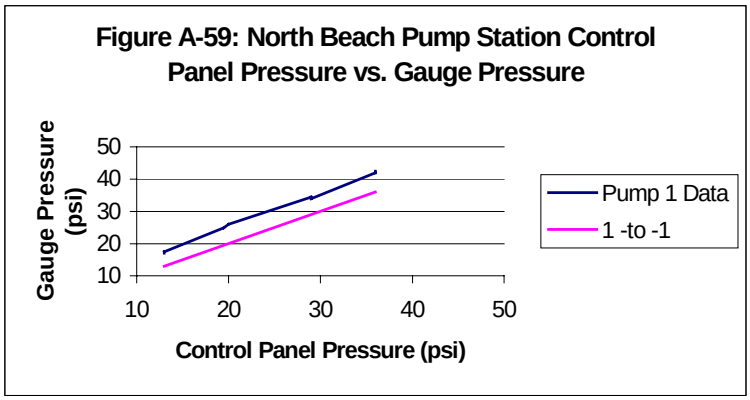


Figure A-59: North Beach Pump Station Control Panel Pressure vs. Gauge Pressure
Gauge Pressure (psi)
50
40
30
20
10
10
20
30
40
50
Control Panel Pressure (psi)
Pump 1 Data
1 -to -1

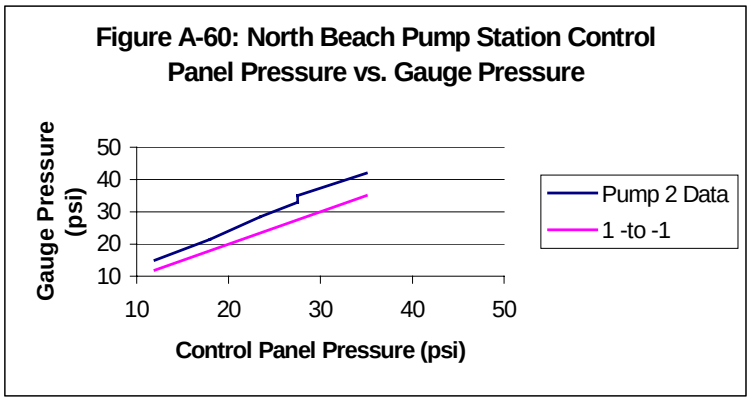


Figure A-60: North Beach Pump Station Control Panel Pressure vs. Gauge Pressure
Gauge Pressure (psi)
50
40
30
20
10
10
20
30
40
50
Control Panel Pressure (psi)
Pump 2 Data
1 -to -1

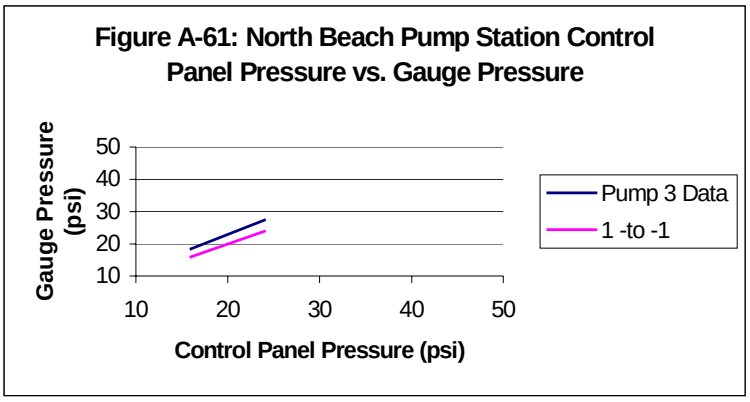


Figure A-61: North Beach Pump Station Control Panel Pressure vs. Gauge Pressure
Gauge Pressure (psi)
50
40
30
20
10
10
20
30
40
50
Control Panel Pressure (psi)
Pump 3 Data
1 -to -1

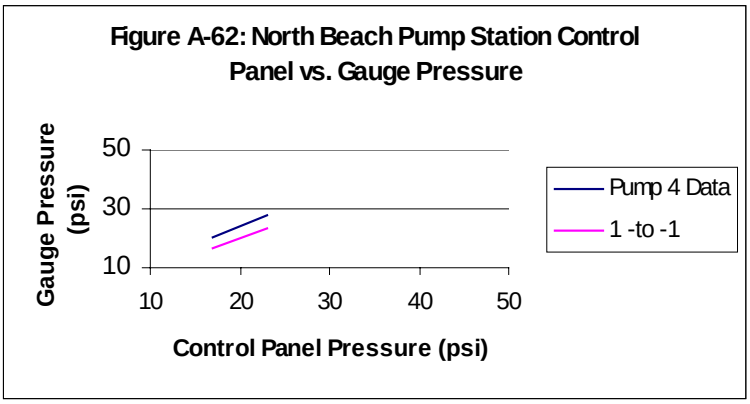


Figure A-62: North Beach Pump Station Control Panel vs. Gauge Pressure
Gauge Pressure (psi)
50
30
10
10
20
30
40
50
Control Panel Pressure (psi)
Pump 4 Data
1 -to -1

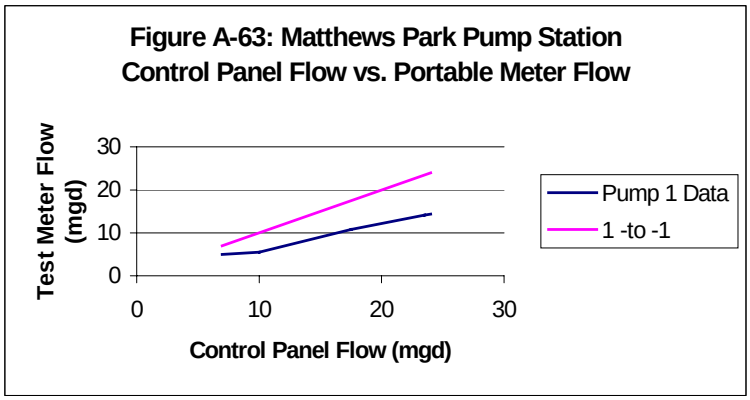


Figure A-63: Matthews Park Pump Station
Control Panel Flow vs. Portable Meter Flow
Test Meter Flow (mgd)
30
20
10
0
0
10
20
30
Control Panel Flow (mgd)
Pump 1 Data
1 -to -1

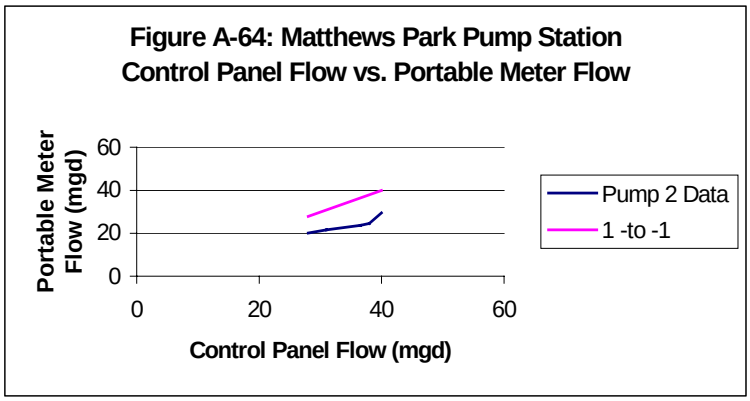


Figure A-64: Matthews Park Pump Station
Control Panel Flow vs. Portable Meter Flow
Portable Meter Flow (mgd)
60
40
20
0
0
20
40
60
Control Panel Flow (mgd)
Pump 2 Data
1 -to -1

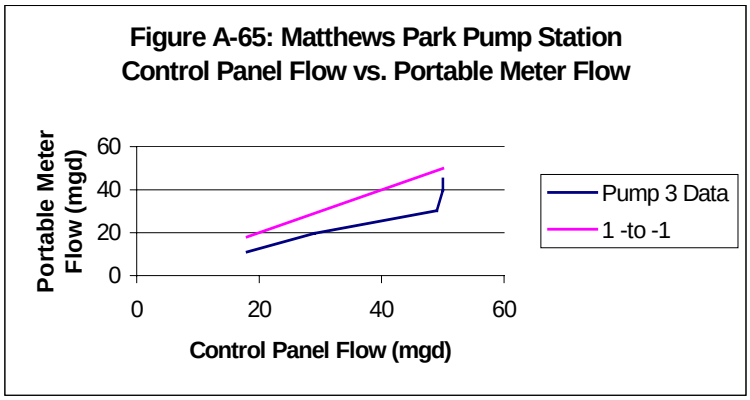


Figure A-65: Matthews Park Pump Station
Control Panel Flow vs. Portable Meter Flow
Portable Meter Flow (mgd)
60
40
20
0
0
20
40
60
Control Panel Flow (mgd)
Pump 3 Data
1 -to -1

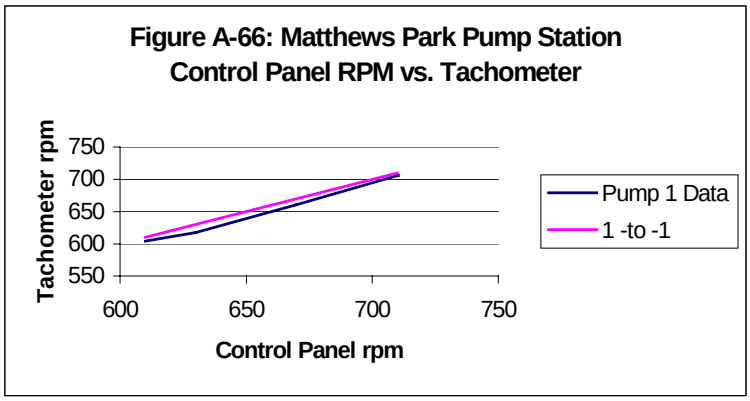


Figure A-66: Matthews Park Pump Station
Control Panel RPM vs. Tachometer
Tachometer rpm
750
700
650
600
550
600
650
700
750
Control Panel rpm
Pump 1 Data
1 -to -1

Figure A-67: Matthews Park Pump Station
Control Panel RPM vs. Tachometer

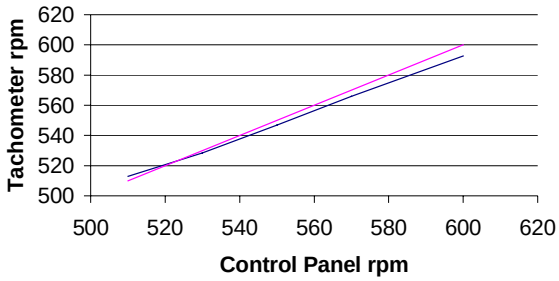


Figure A-68: Matthews Park Pump Station
Control Panel RPM vs. Tachometer

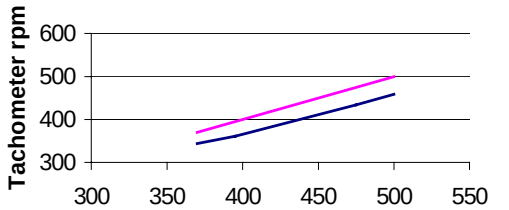


Figure A-69: Matthews Park Pump Station
Control Panel WW El. vs. CATAD

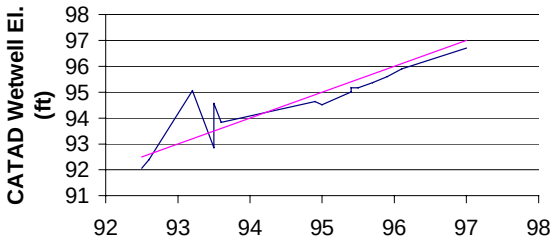


Figure A-70: Matthews Park Pump Station
Control Panel Flow vs. CATAD Flow

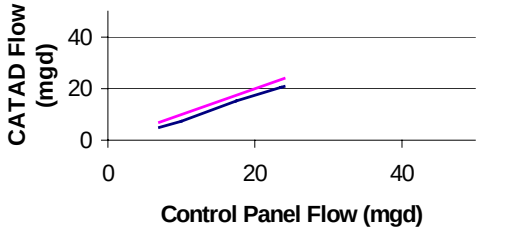


Figure A-71: Matthews Park Pump Station
Control Panel Flow vs. CATAD

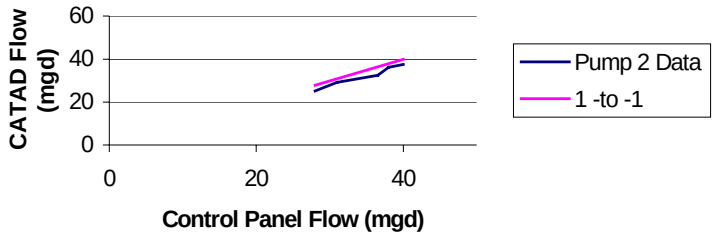


Figure A-72: Matthews Park Pump Station
Control Panel Flow vs. CATAD - Pump #3

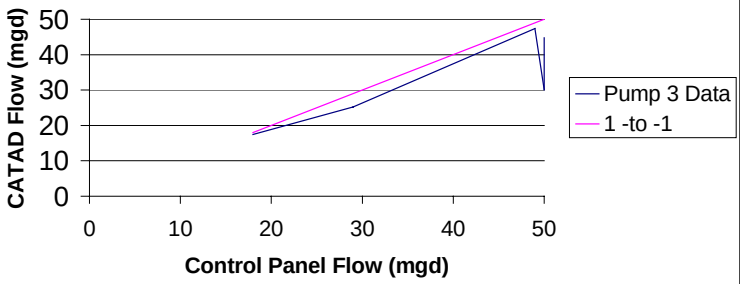


Figure A-73: Matthews Park Pump Station
Control Panel vs. CATAD RPM

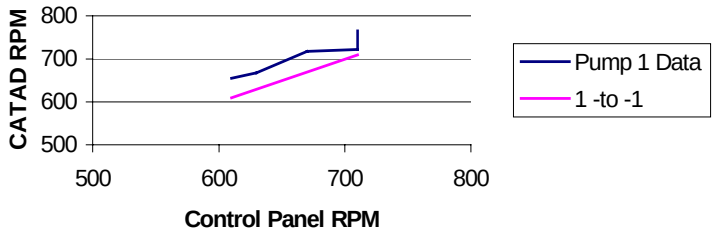
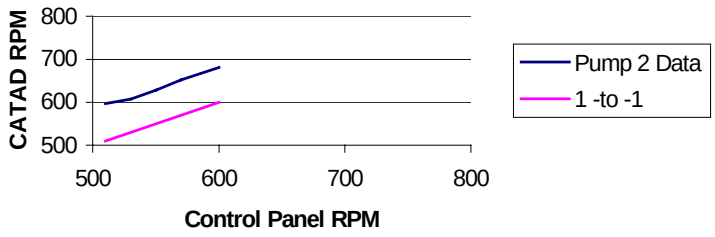


Figure A-74: Matthews Park Pump Station
Control Panel vs. CATAD RPM



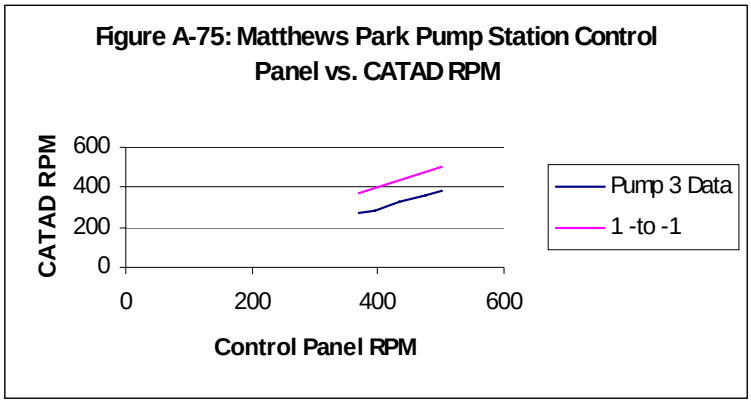


Figure A-75: Matthews Park Pump Station Control Panel vs. CATAD RPM
CATAD RPM
600
400
200
0
0
200
400
600
Control Panel RPM
Pump 3 Data
1 -to -1

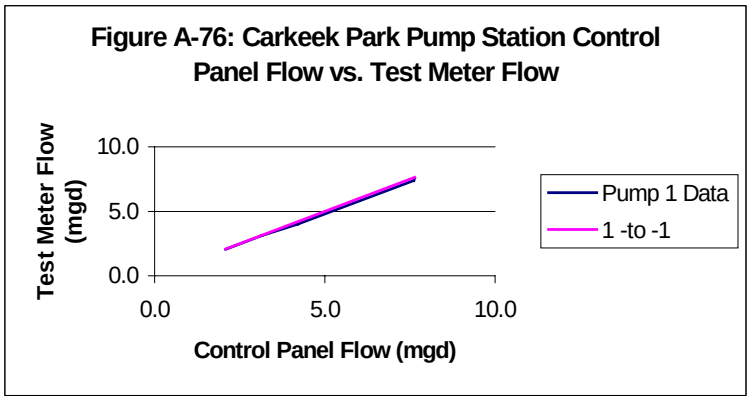


Figure A-76: Carkeek Park Pump Station Control Panel Flow vs. Test Meter Flow
Test Meter Flow (mgd)
10.0
5.0
0.0
0.0
5.0
10.0
Control Panel Flow (mgd)
Pump 1 Data
1 -to -1

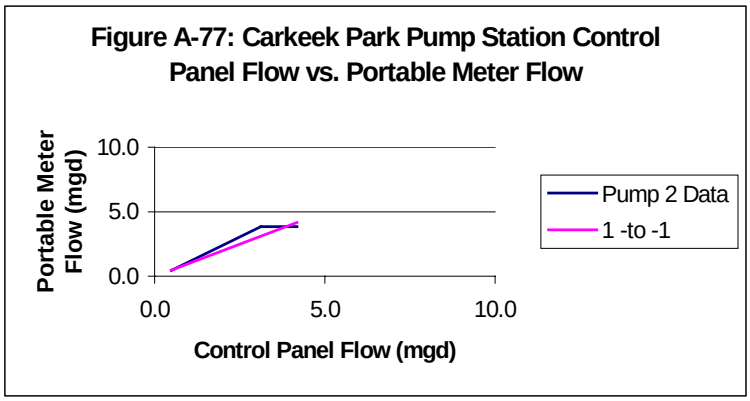


Figure A-77: Carkeek Park Pump Station Control Panel Flow vs. Portable Meter Flow
Portable Meter Flow (mgd)
10.0
5.0
0.0
0.0
5.0
10.0
Control Panel Flow (mgd)
Pump 2 Data
1 -to -1

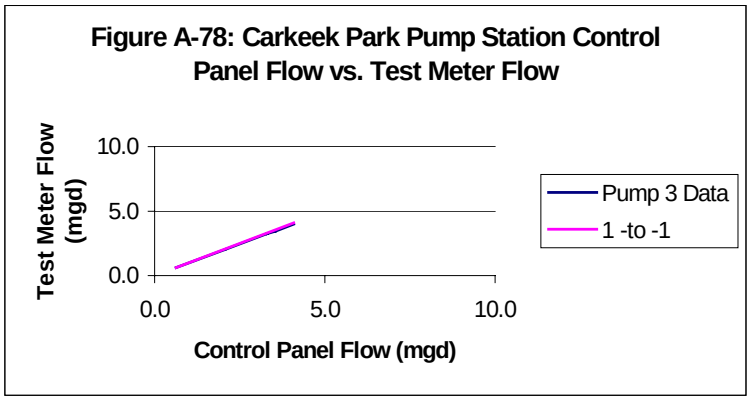


Figure A-78: Carkeek Park Pump Station Control Panel Flow vs. Test Meter Flow
Test Meter Flow (mgd)
10.0
5.0
0.0
0.0
5.0
10.0
Control Panel Flow (mgd)
Pump 3 Data
1 -to -1

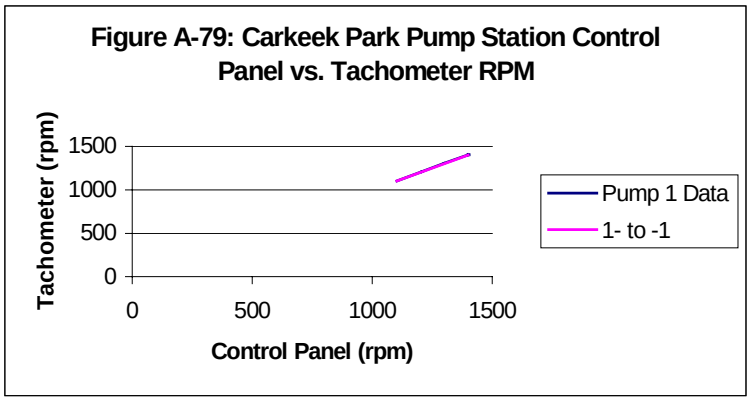


Figure A-79: Carkeek Park Pump Station Control Panel vs. Tachometer RPM
Tachometer (rpm)
1500
1000
500
0
0
500
1000
1500
Control Panel (rpm)
Pump 1 Data
1- to -1

Figure A-80: Carkeek Park Pump Station Control Panel vs. Tachometer RPM

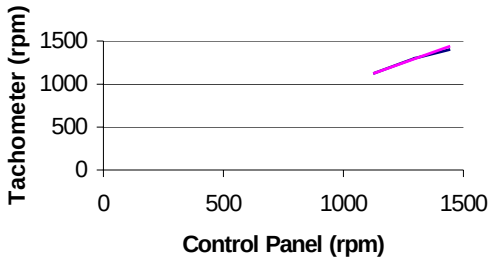


Figure A-81: Carkeek Park Pump Station Control Panel vs. Tachometer RPM

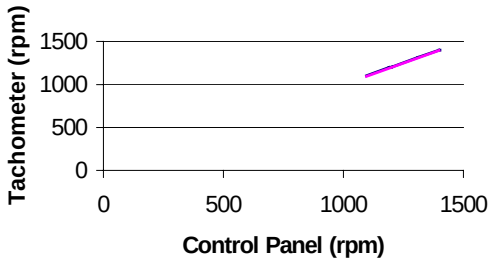


Figure A-82: Carkeek Park Pump Station Control Panel vs. Pressure Gauge

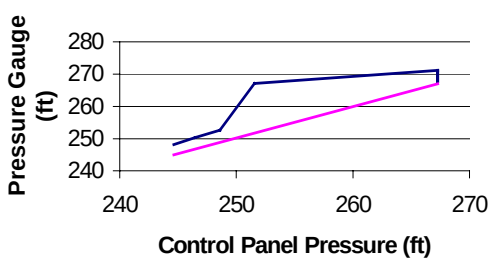
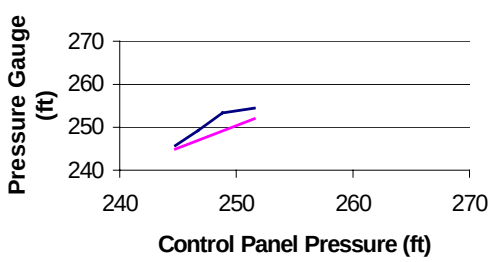


Figure A-83: Carkeek Park Pump Station Control Panel vs. Pressure Gauge



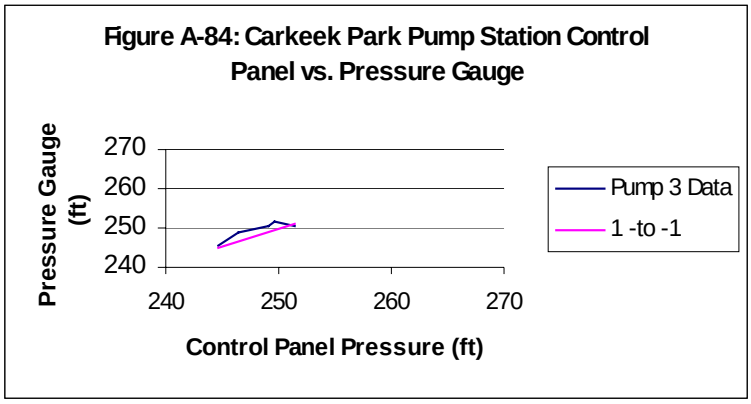


Figure A-84: Carkeek Park Pump Station Control Panel vs. Pressure Gauge
Pressure Gauge (ft)
270
260
250
240
240
250
260
270
Control Panel Pressure (ft)
Pump 3 Data
1 -to -1

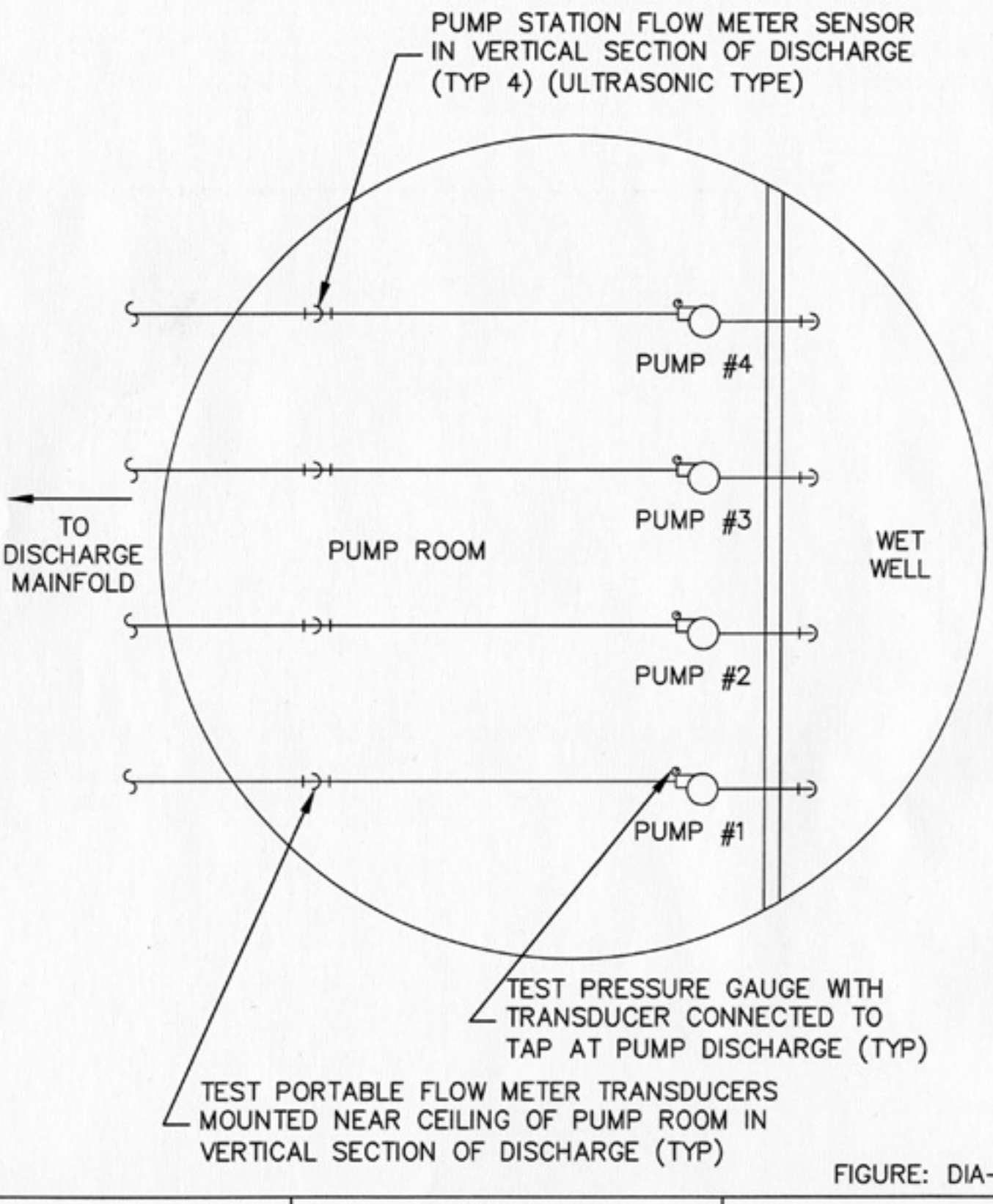


FIGURE: DIA–1

GARRY STRUTHERS ASSOCIATES, INC.
3150 Richards Road, Suite 100
Bellevue, WA 98005-4448
Phone: (425) 519-0300
Fax: (425) 519-0309
E-mail: gsa@gsaseco-inc.com
http://www.gsaseco-inc.com

KENMORE PUMP STATION ONE LINE DIAGRAM

KING COUNTY CSI

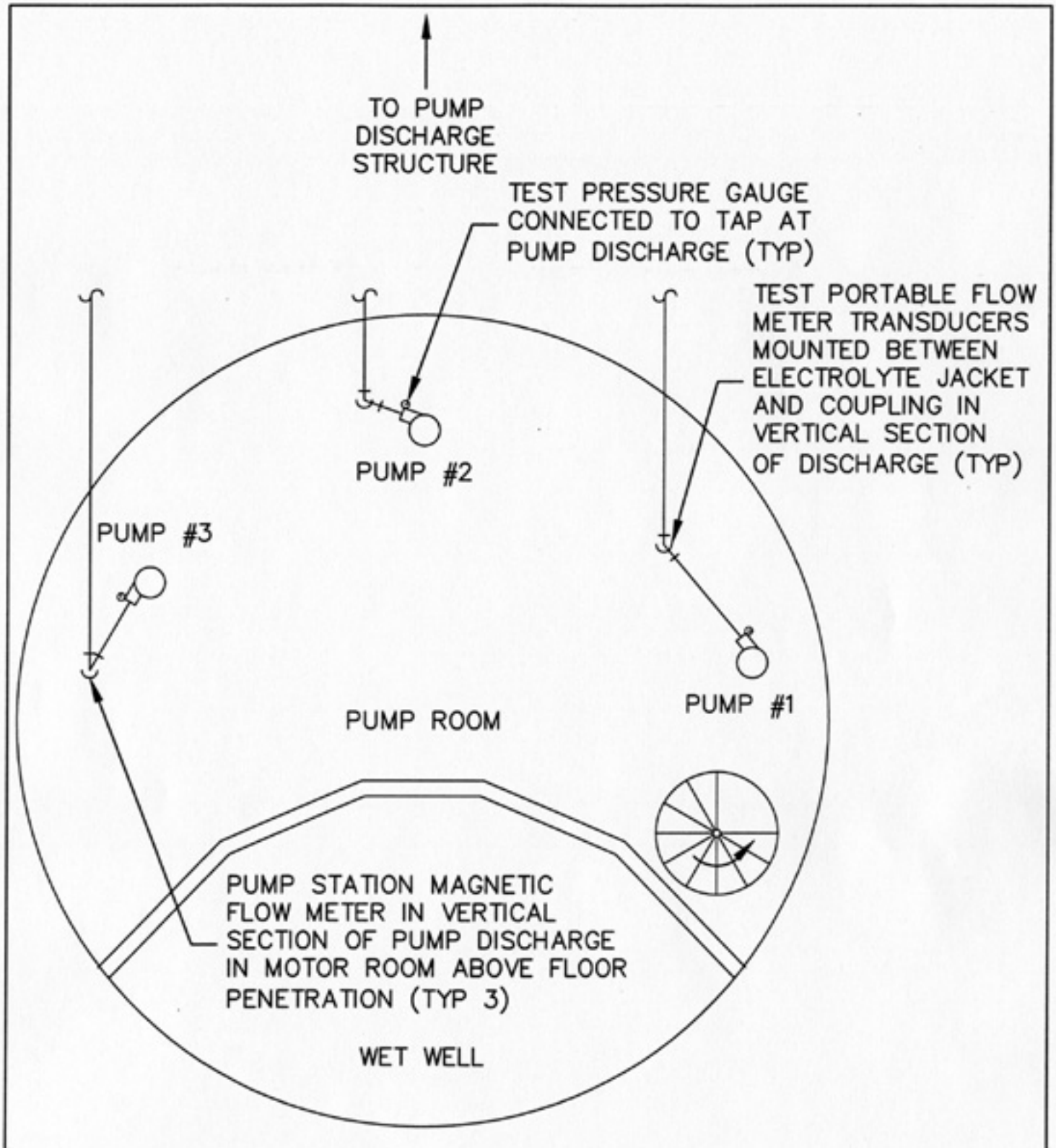


FIGURE: DIA–2

GARRY STRUTHERS ASSOCIATES, INC.	WOODINVILLE PUMP STATION ONE LINE DIAGRAM	KING COUNTY CSI

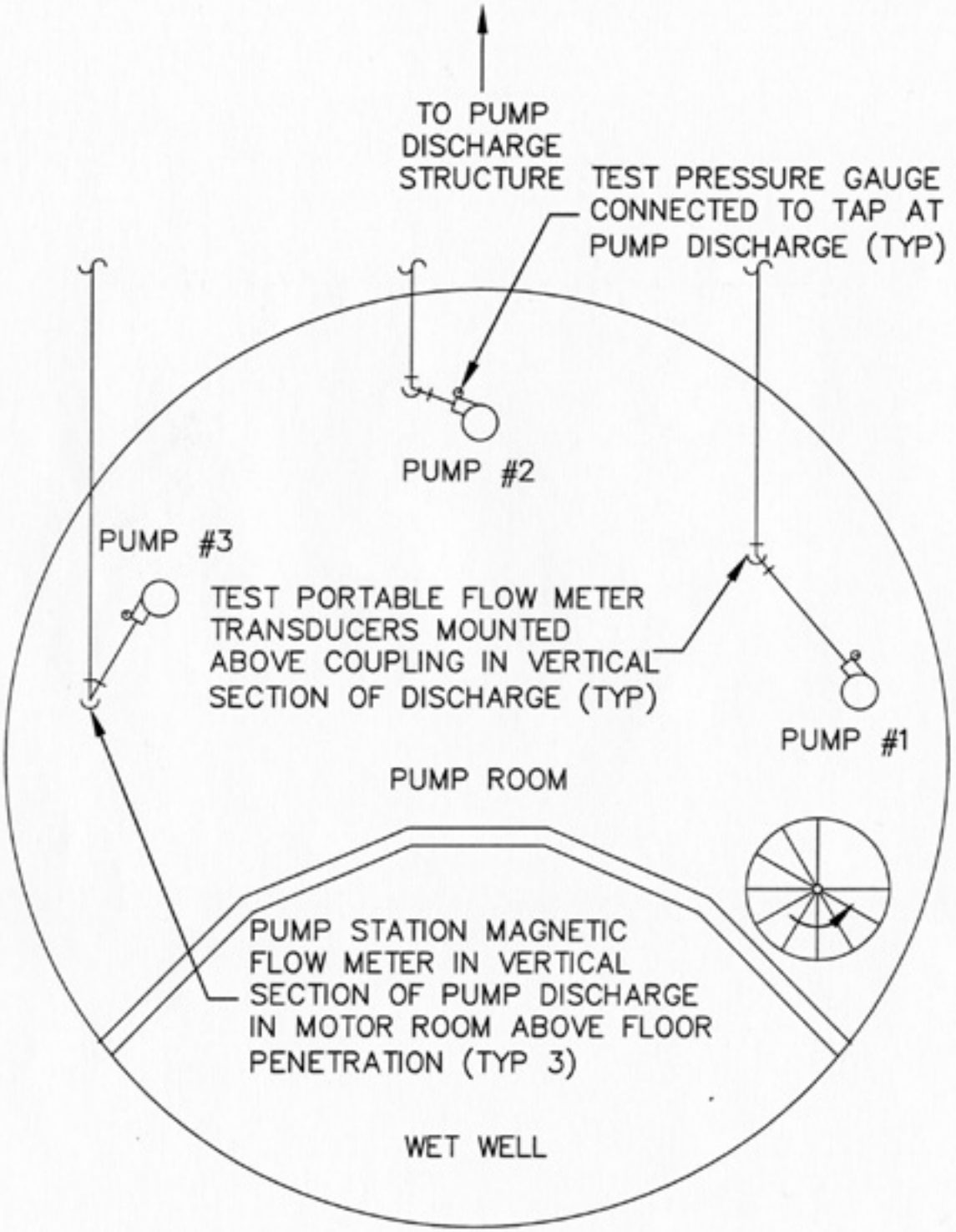


FIGURE: DIA–3

GARRY STRUTHERS ASSOCIATES, INC.
3150 Richards Road, Suite 100
Bellevue, WA 98005-4448
Phone: (425) 519-0300
Fax: (425) 519-0309
E-mail: gsa@gsassoc-inc.com
http://www.gsassoc-inc.com

HOLLYWOOD PUMP STATION ONE LINE DIAGRAM

KING COUNTY CSI

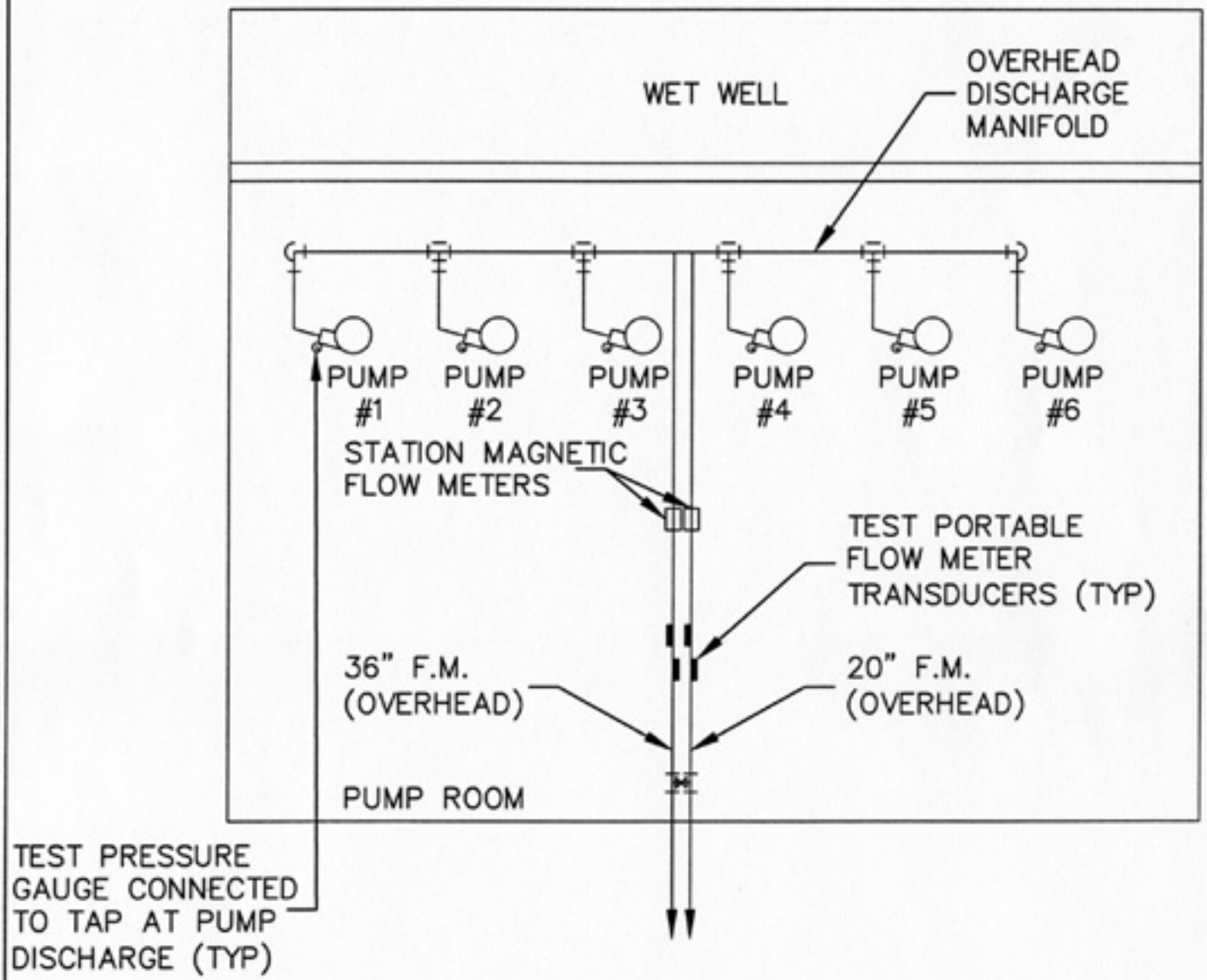


FIGURE: DIA–4

GARRY STRUTHERS ASSOCIATES, INC.
3150 Richards Road, Suite 100
Bellevue, WA 98005-4448
Phone: (425) 519-0500
Fax: (425) 519-0509
E-mail: gsa@gsaseco-inc.com
http://www.gsaseco-inc.com

YORK PUMP STATION ONE LINE DIAGRAM

KING COUNTY CSI

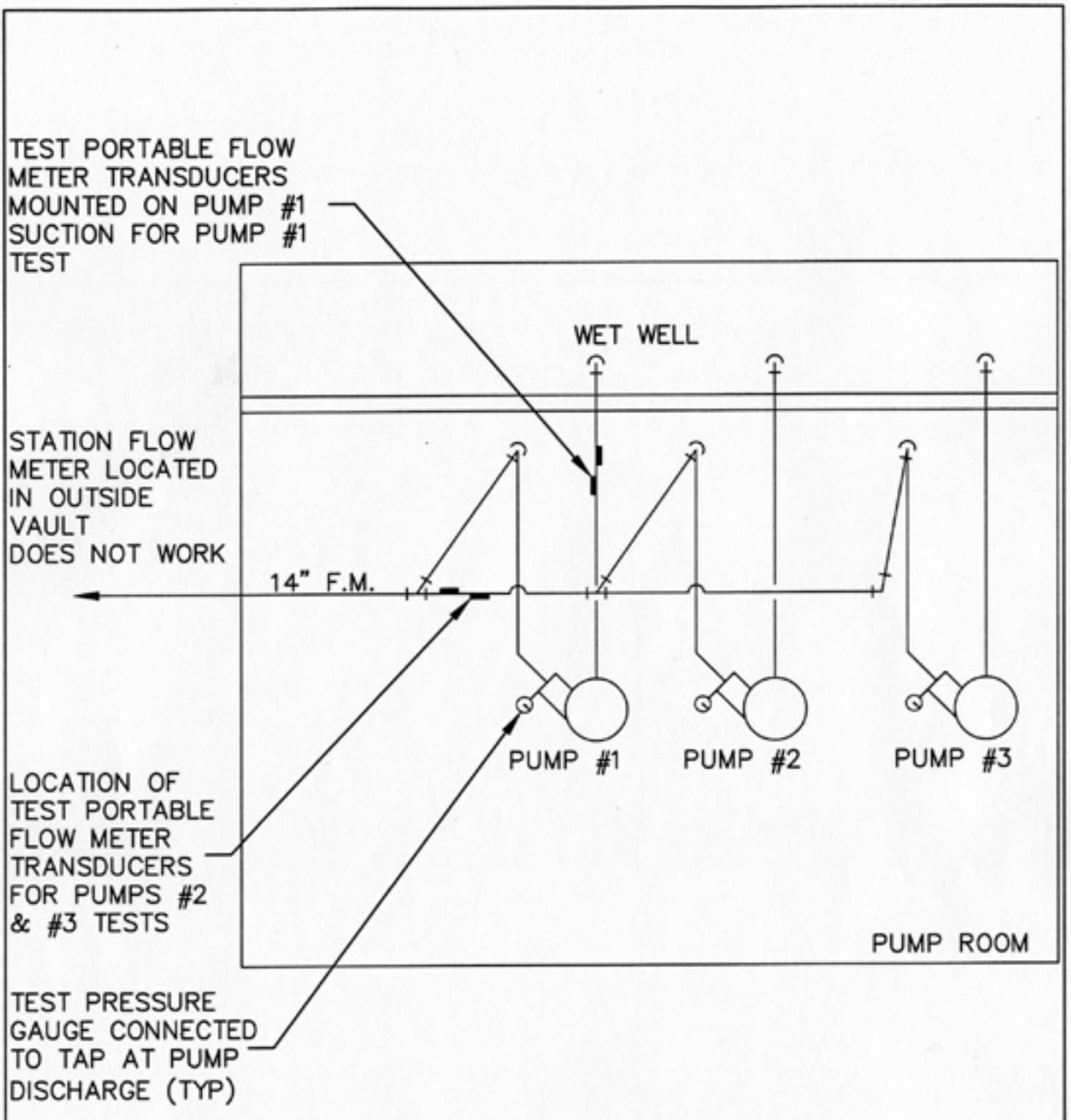


FIGURE: DIA–5

GARRY STRUTHERS ASSOCIATES, INC.
3180 Richards Road, Suite 100
Bellevue, WA 98005-4448
Phone: (425) 519-0300
Fax: (425) 519-0309
E-mail: gsa@gsaseco-inc.com
http://www.gsaseco-inc.com

HIDDEN LAKE PUMP STATION ONE LINE DIAGRAM

KING COUNTY CSI

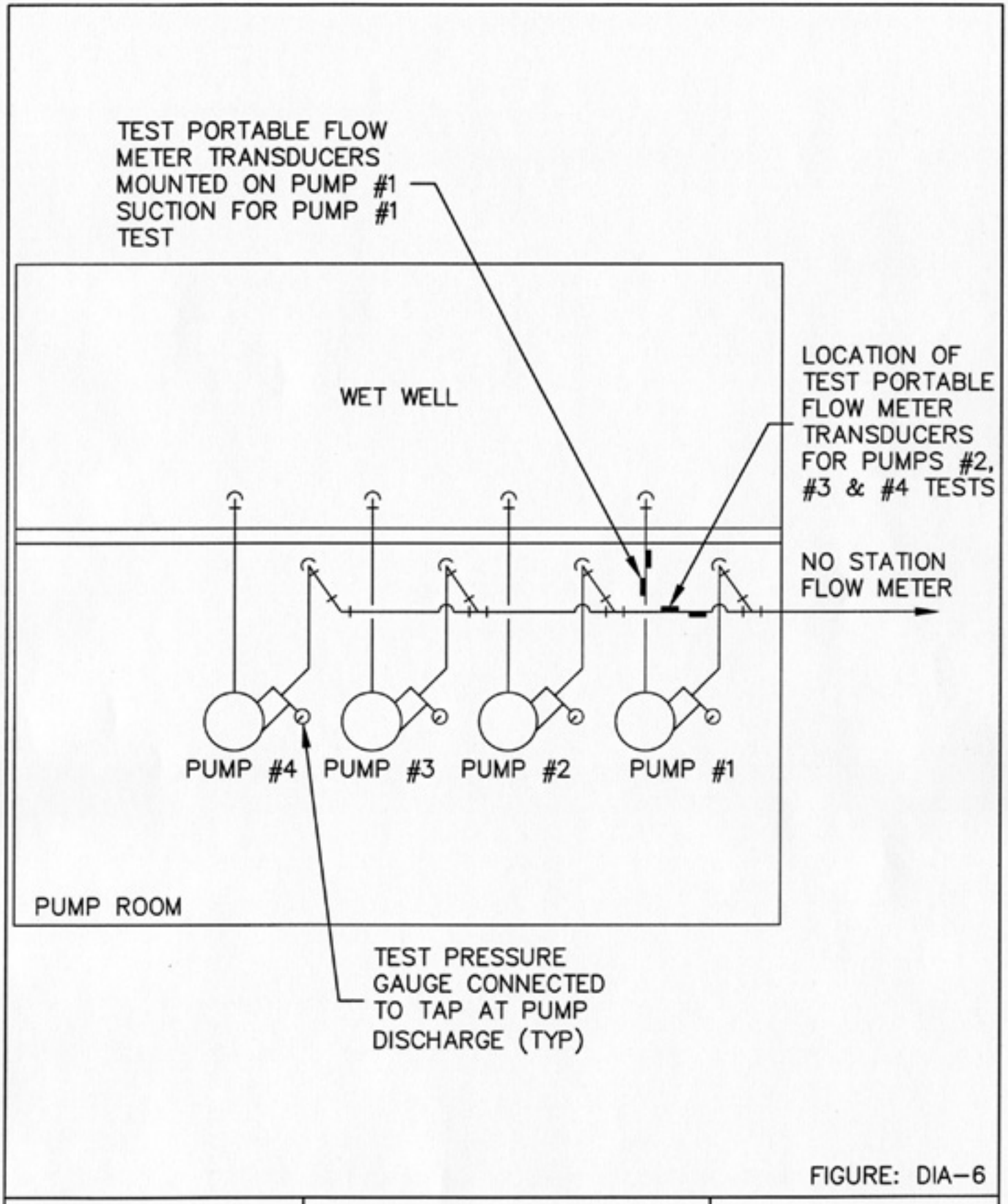


FIGURE: DIA–6

GARRY STRUTHERS ASSOCIATES, INC.
3150 Richards Road, Suite 100
Bellevue, WA 98005-4448
Phone: (425) 519-0300
Fax: (425) 519-0308
E-mail: gsa@gsaseco-inc.com
http://www.gsaseco-inc.com

NORTH BEACH PUMP STATION ONE LINE DIAGRAM

KING COUNTY CSI

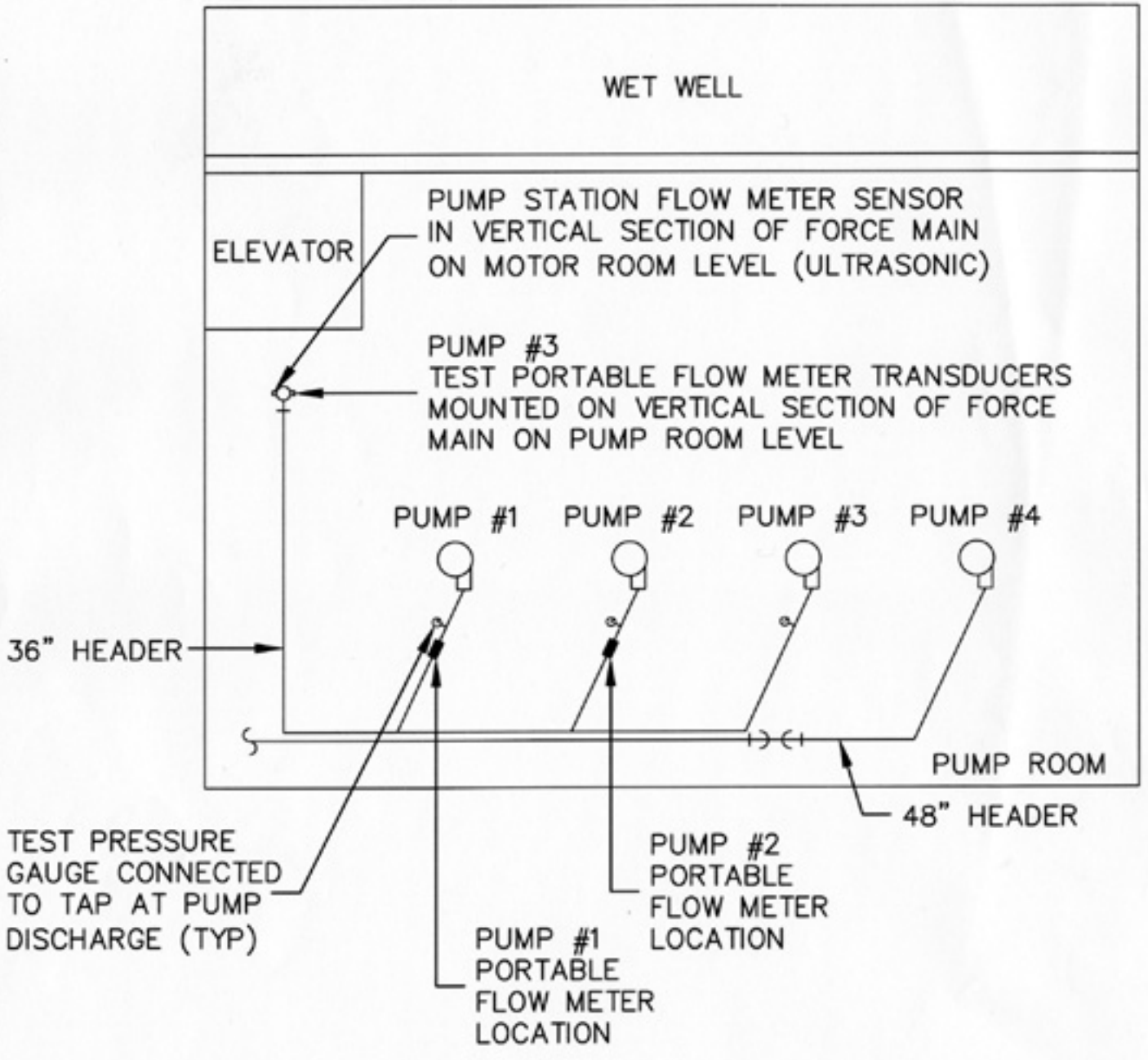
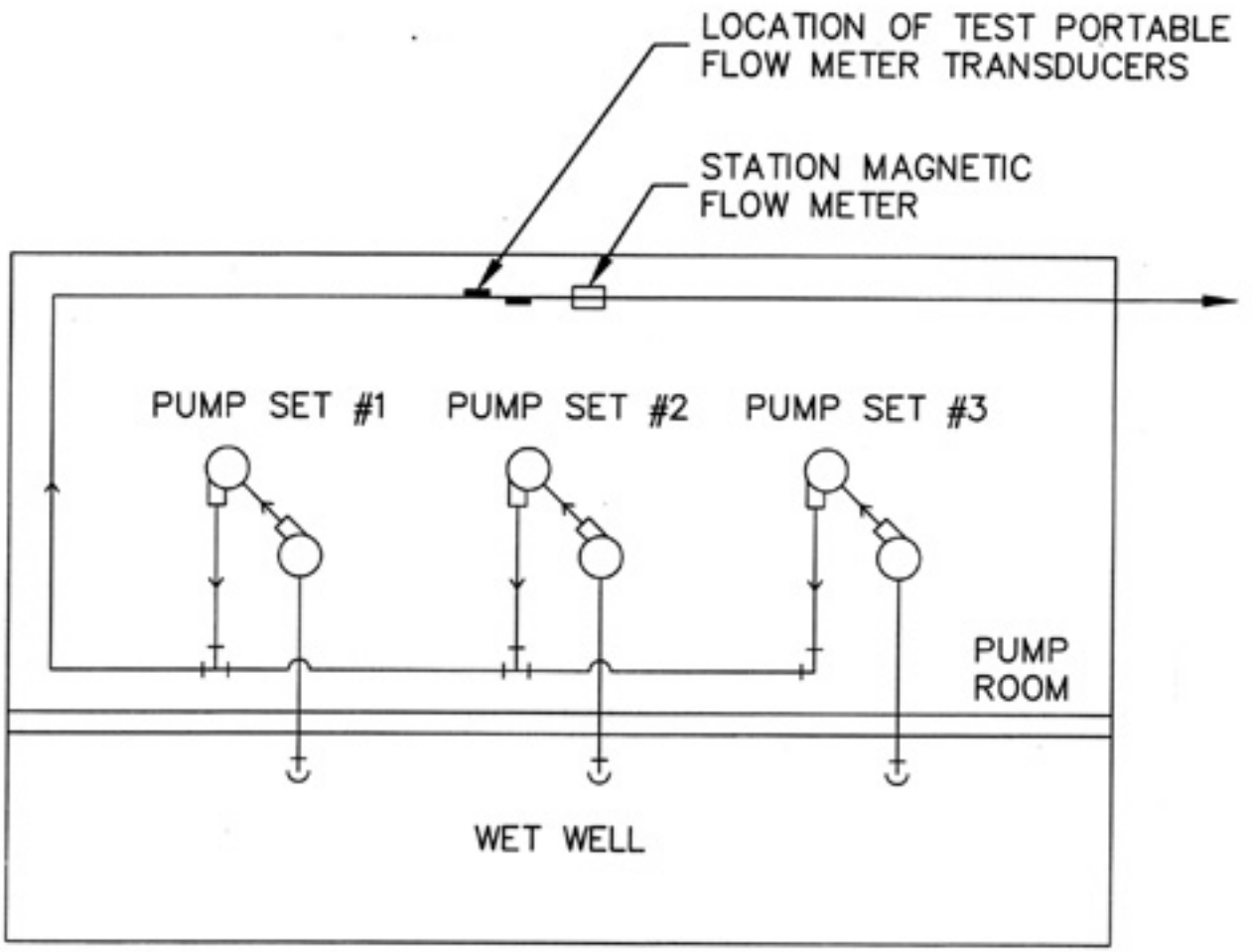


FIGURE: DIA–7

GARRY STRUTHERS ASSOCIATES, INC.
3150 Richards Road, Suite 100
Bellevue, WA 98005-4448
Phone: (425) 519-0300
Fax: (425) 519-0309
E-mail: gsa@gsaseco-inc.com
http://www.gsaseco-inc.com

MATTHEWS PARK PUMP STATION ONE LINE DIAGRAM

KING COUNTY CSI



NOTE: TEST PRESSURE GAUGES WERE NOT ATTACHED DUE TO THE HIGH STATIC HEAD AND CONFIGURATION OF GAUGE CONNECTIONS. THE IN-STATION PRESSURE MEASUREMENT WAS TAKEN FROM THE CONTROL PANEL. NOT SURE OF THE LOCATION OF THE F.M. PRESSURE GAUGE.

FIGURE: DIA-8

GARRY STRUTHERS ASSOCIATES, INC.
3150 Richards Road, Suite 120
Bellevue, WA 98005-4448
Phone: (425) 519-0300
Fax: (425) 519-0308
E-mail: gsa@gsaseco-inc.com
http://www.gsaseco-inc.com

CARKEEK PARK
PUMP STATION
ONE LINE DIAGRAM

KING COUNTY
CSI